DEC 1934

Metal PROGRESS

THE AMERICAN SOCIETY FOR METALS

Published by the American Society for Metals

Metal Progress

table of contents

Vol. 26, No. 6 Dec., 1934

Published and copyrighted, 1934, by the American Society for Metals, 7016 Euclid Avenue, Cleveland, Ohio. . . . Issued monthly, subscription $5 a year, current copies 50c. . . . Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, O., under the Act of March 3, 1870. . . . American Society for Metals is not responsible for statements or opinions in this publication. Editorials are written by the editor and represent his views. He is also sponsor for unsigned and staff articles. . . . Ernest E. Thum, Editor.

Linde Process Service

saves

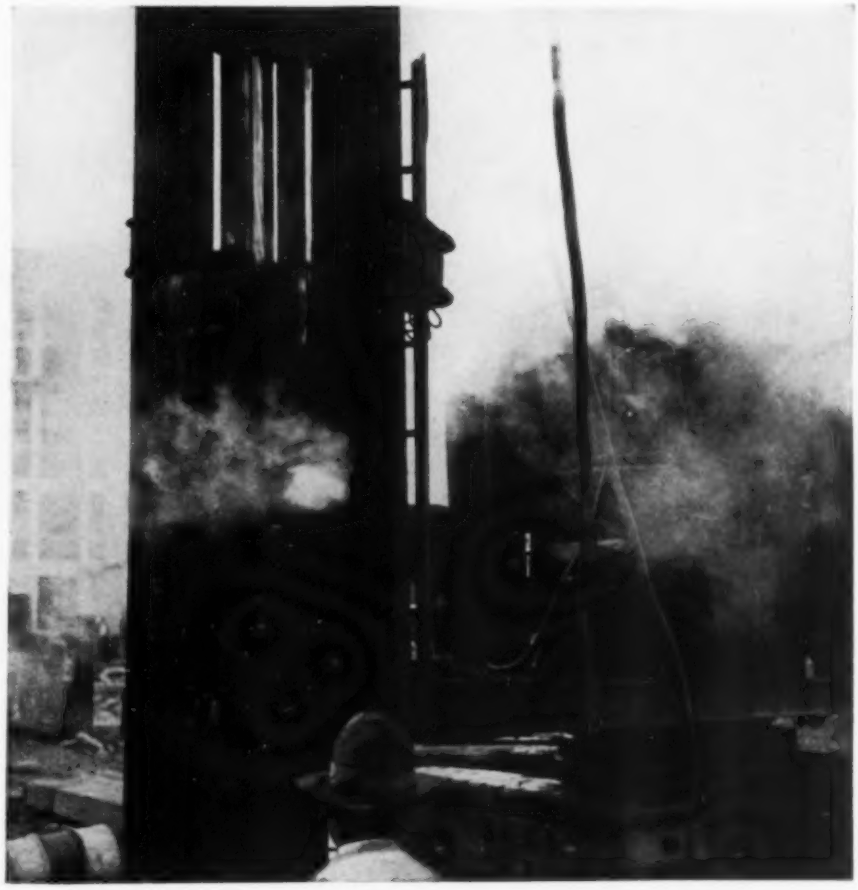
$354

IT looked as if nothing could prevent the expenditure to replace the fractured steam hammer cylinder on the foundation company's pile driver.

A Linde Service Operator was called and, on examining the cylinder, found that it could be made as good as new by bronze-welding. With his cooperation the work was rapidly completed. The cost of materials and labor amounted to about $31—a saving of $354 over the cost of $385 for a new cylinder. Tests proved that the bronze-welded repair was fully capable of withstanding the severe service of everyday operation. The foundation company was highly pleased with the result.

Thus does Linde Process Service work to save time and money for users of Linde Oxygen. It makes available, from the melting pot of thousands of experiences in many industries, sound welding and cutting practices that have a direct bearing on your particular problems. The value of this unique service is further amplified by coordination with the vast resources, scientific research and engineering facilities of other Units of Union Carbide and Carbon Corporation.

Ask your nearest Linde Sales Office how Linde Process Service can be of assistance. These are located in Atlanta, Baltimore, Birmingham, Boston, Buffalo, Butte, Chicago, Cleveland, Dallas, Denver, Detroit, El Paso, Houston, Indianapolis, Kansas City, Los Angeles, Memphis, Milwaukee, Minneapolis, New Orleans, New York, Philadelphia, Phoenix, Pittsburgh, Portland, Ore., St. Louis, Salt Lake City, San Francisco, Seattle, Spokane and Tulsa. Everything for oxy-acetylene welding and cutting—including Linde Oxygen, Prest-O-Lite Acetylene, Union Carbide and Oxweld Apparatus and Supplies—is available from Linde through producing plants and warehouse stocks in all industrial centers.



FULL STEAM AHEAD—Quick-time repair by bronze-welding fractured steam hammer cylinder saves money—cuts delay on job.

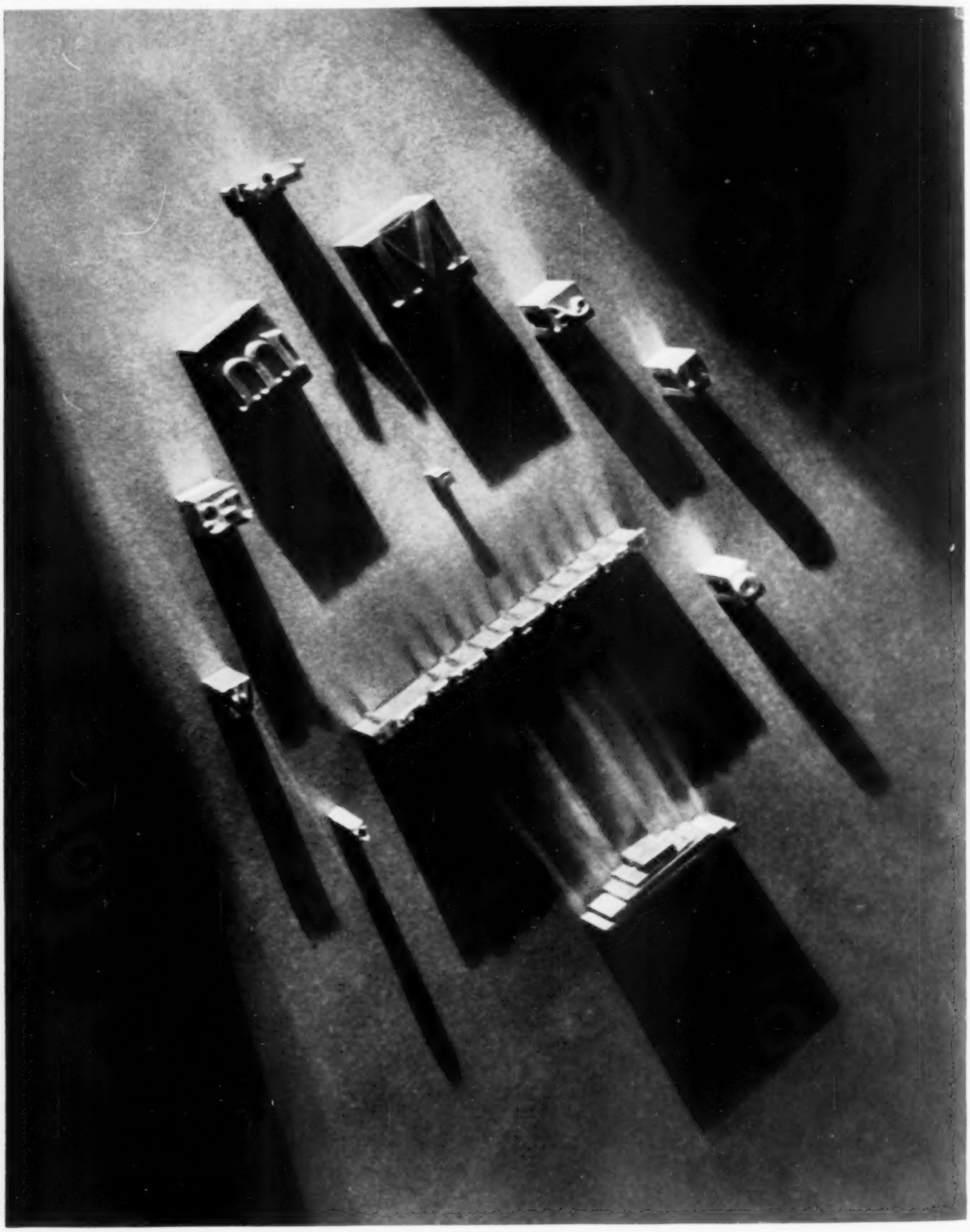
PRODUCT OF A UNIT OF UCC UNION CARBIDE AND CARBON CORPORATION

The Linde Air Products Company

Unit of Union Carbide and Carbon Corporation

In Canada: Dominion Oxygen Co. of Canada, Ltd.

YOU CAN ORDER EVERYTHING FOR OXWELDING AND CUTTING FROM LINDE



Mr. Rittase Visited Haddon Press in Camden and Photographed Some Type

Type Metals

Foundry type, so-called, which is set by hand and used over and over again, is of a harder alloy than linotype metal, which is primarily used for preparing a more durable stereotype or electrotype plate for the presses. The lead-antimony-tin alloys possess many desirable characteristics for such purposes, chief among them being the ability to reproduce fine detail. The oft-stated reason — that these alloys expand on solidification — is proven, on investigation, to be incorrect.

THE FIRST printer's type of cast metal was made about four and a half centuries ago. Practically continuous progress in the casting art has led from crude hand-operated molds to the modern methods for casting type in which the art and science of molding metals has reached its highest development. Yet, the modern type-casting machine (which can cast a piece of type, trim it to within a few ten thousandths of an inch of a predetermined size, and place it in its correct position in a line of type — all within one third of a second) uses the same family of lead-rich lead-tin-antimony alloys which was the foundation of the art of printing from movable cast metal type. Although our technical literature contains very little information on these alloys there can be no doubt but that much research work has been done, especially within recent years, and has given the printer alloys which are free from impurities and free from non-metallic inclusions. For each application a rather narrow range of composition has been found to be best. For particular purposes the addition of a fourth element (usually in small amounts) has resulted in improved quality.

Type is now cast by machines which may readily be classified into two groups, according to their final product. One of these groups of machines casts the hot alloy into a slot against a row of matrices to form an entire line of type along the top edge of a single casting known as a "line-slug." The operator of the machine works a key board not radically different from a typewriter key board in appearance; a touch on an appropriate key releases a letter-matrix from a magazine which drops into place in the growing line.

The other group of machines casts individual letters; this "monotype" machine may be used to cast any desired number of any single character, or spaces, which can then be placed in cases and set by hand. They are also used as composing machines, when two distinct operations on different machines are involved. The operator works a key board on a machine which makes perforations in a paper ribbon. This perforated ribbon is later fed into the caster which automatically casts the correct pieces of type, one after another and ejects them into forms, all in the correct order, correctly spaced, and divided into lines — really a mechanical marvel.

Relative advantages of the two classes of machines are such that each has found a definite place in the printing industry. Line-o'-type machines are very fast and the type is easy to handle, which gives them an advantage in newspaper work. The monotype machines are quite extensively used for printing books, magazines, advertising matter, and for job printing. A particular

By H. Vance White
Instructor in Metallurgy
Virginia Polytechnic Institute
Blacksburg, Virginia

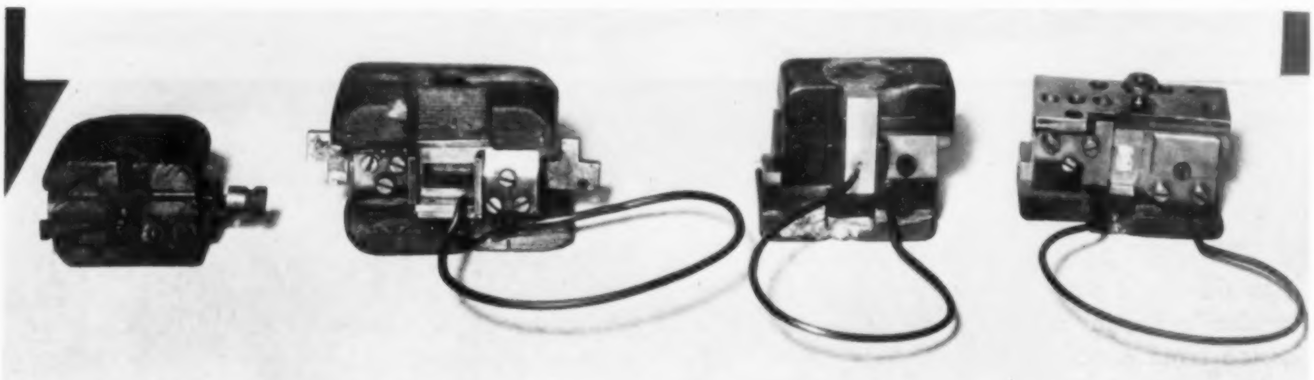
advantage of the monotype for books is that the perforated ribbons may be saved for future editions and then merely fed through the caster; thus the type can be reset very quickly and at considerably less expense, as it is not necessary to repeat the work at the key board. (METAL PROGRESS is set in linotype; the headlines are monotype or foundry type, hand set.)

In few other cases is the application of a metal dependent upon so many of its characteristics as are the type-metal alloys. The properties which are of vital importance range from the chemical activity of the molten metals to the physical properties of the solid type. The alloys suitable for casting type may be divided into five classes; there are other very special alloys but as their applications are so restricted space does not warrant their description. The five classes now used all fall near the lead corner of the lead-tin-antimony equilibrium diagram. The compositions are all within the range; tin 3 to 14 per cent, antimony 3 to 24 per cent, the remainder lead. These are considerably higher in lead than formerly thought advisable for a hard type for modern press work. For instance, Gulliver's "Metallic Alloys" printed in 1913 says "the usual composition lies between lead 50 to 60%, antimony 25 to 30, and tin 25 to 10%."

The properties of these 1934 type-metal alloys naturally depend upon their structures. From this standpoint we may arrange the five classes under three groups: First, linotype metal which is a mixture of the two binary eutectics, lead-antimony and lead-tin; second, electrotype metal which is a mixture of these two eutectics plus excess lead; third, stereotype, monotype and hard foundry metals which are mixtures of these two eutectics plus excess antimony and tin.

U. S. Government Printing Office has standardized on a composition of 4.0 to 4.5% of tin, 11.5% antimony, remainder lead, for linotype metal. Metal of this composition is strong enough to withstand the pressure of a printing press, especially in large forms (assemblages of type), but its hardness and abrasion resistance are so small that the type will give only a few thousand good clean impressions. Slugs cast by linotype machines are used directly on the presses for short runs; however, when a great number of good impressions are desired, the linotype slugs are merely the first step in preparing the "type" which is to do the actual printing, known as a stereotype or an electrotype.

In stereotyping, a form is assembled of all the type necessary for a large page (or for several small pages) of printed matter, correctly arranged and securely locked together. A papier-mache mat, properly dampened, is then tightly pressed onto the surface of the form and allowed to dry in place. If a slightly dampened mat is used on a steam table this may be accomplished in a very few minutes, as when preparing special editions of newspapers. When removed the mat carries a faithful reproduction of the form — in negative, of course. This mat is placed in a casting box and stereotype metal poured against it. The resulting casting or "plate," as it is called, will be a reproduction of the top surface of the original form, faithful in all details, except that it is slightly smaller due to drying and solidification shrinkage of mat and stereotype metal. These plates may be flat



Hand Type Molds in Museum of American Type Founders Co.

First is an early 16th century mold. Next is one (without matrix) dating from the 18th century; it is hinged at the rear, and the parting line is at the diagonal edges of the cavity. The other two are 20th century molds; one has the matrix held in position by the hoop-like spring; in the other the matrix has been removed, showing a type

to be mounted on flat-bed presses, or they may be curved so that two of them can be mounted together to form a cylinder for the high speed rotary presses.

The Government Printing Office (which has done much work on investigating printer's materials) has also found that an alloy containing 6.5 to 7.0% tin, 12.75 to 13.00% antimony, remainder lead, is very satisfactory for stereotype work. As this alloy contains antimony and tin in excess of eutectic proportions it will contain crystals of the intermetallic compound SbSn which are very hard and will impart considerable abrasion resistance to the alloy. Metal of this composition will give 70,000 clear impressions on news print paper.

In electrotyping an impression is made of the desired matter in wax or very soft lead. After some necessary preliminary treatment the wax or lead impression is placed in an electrolytic bath and a layer of copper (or first nickel, then copper) deposited to form a thin shell which is to be the printing face of the type. This shell is then carefully stripped from the wax, placed in a mold and built up to the proper thickness with electrotype or backing metal. Before pouring on the electrotype metal the back of the shell is treated with a suitable flux and covered with a sheet of so-called tin foil (really lead-tin solder foil) to promote an effective bond, for there is a surprisingly large suction from inking rollers or the sheet of paper passing rapidly over the type, so the latter must be securely anchored.

The copper or nickel shell takes up all abrasion and the electrotype metal needs only sufficient strength to withstand the impression and the suction mentioned above. It is very important that the electrotype alloy have the ability to form a tight bond with the copper shell; a composition of 3.0% tin, 3.0% antimony, remainder lead, is typical.

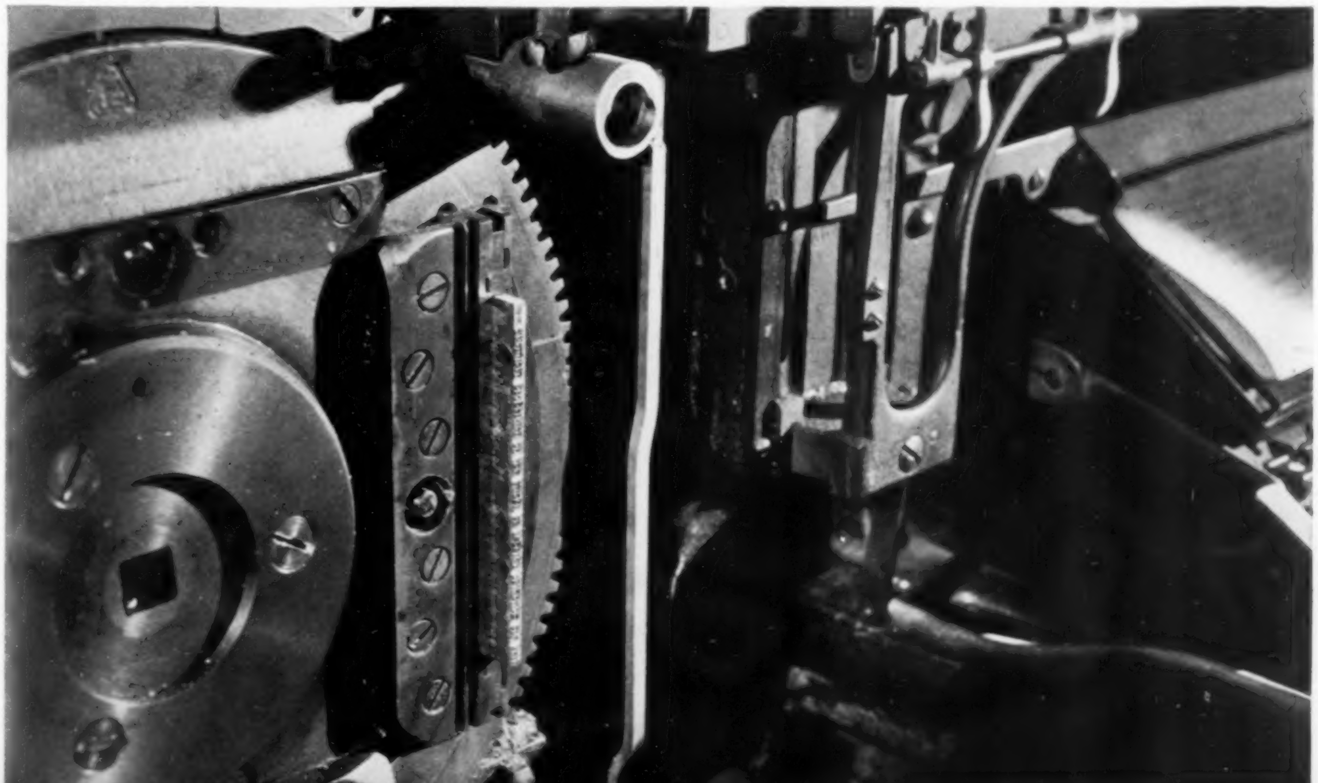
The copper or nickel printing surface is much used in printing labels, books and magazines because of the excellent quality of the printed impressions and the large number of good impressions which it will give. A nickel plate offers the additional advantage of being highly resistant to the severe corrosive action of some of the colored inks. Chromium plate is frequently used for runs of several hundred thousand.

Metal for Movable Type

The composition of monotype metal varies considerably. To give some general values it may vary from 6.0% tin, 16.0% antimony, to 9.0% tin, 19% antimony, remainder lead. The composition is governed by the specific requirements of the individual plant. The higher the tin and antimony the more expensive the original metal, and the higher the temperatures required to handle it.

Type from monotype machines has a very beautiful clear face. The above proportions of tin and antimony are such that the metal is strong, hard, and very resistant to abrasion, and a very large number of good clean impressions may be taken directly from forms set in such

Casting Wheel on Linotype, With Front Removed to Show Slug Being Ejected. It is cast in horizontal position, and after matrixes are removed the wheel turns 90° and pushes the slug out between trimming knives

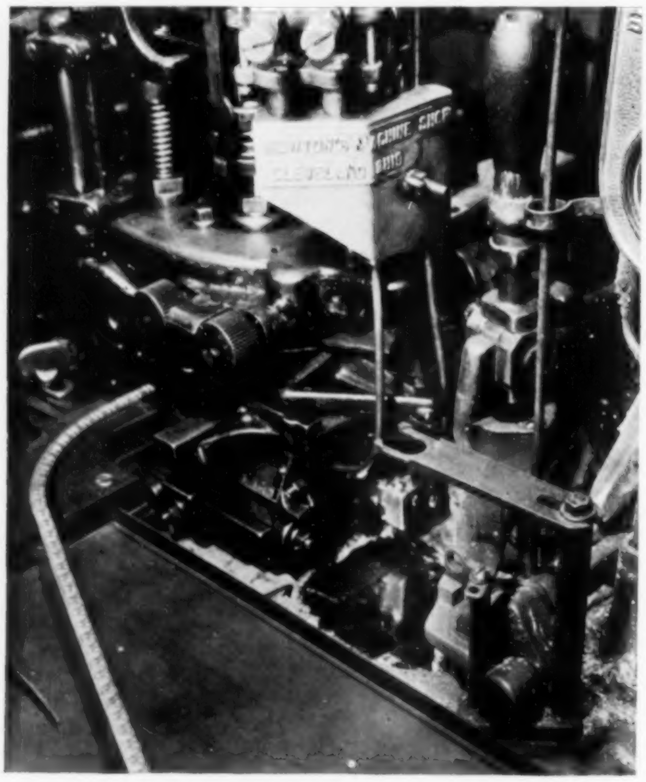


type. In many plants where long runs are seldom encountered, regular linotype metal (or something very similar to it) is often used for monotype.

The last group of alloys is the "foundry" type alloys. Foundry type, of course, antedates all the other classes of type, and up to 50 years ago was the sole reliance of all but the largest printing plants. Originally it was cast by hand. Today practically all of it is cast by machines of the monotype class. Alloys for this class of type will approach the composition of 14.0% tin, 24% antimony, remainder lead. To secure increased abrasion resistance a little copper (0.5%) is sometimes added.

Foundry type metal is the strongest, hardest, and most abrasion-resistant of the type metals. Such type is distributed in cases, a compartment for each letter or character, and composed or set by hand. It is used repeatedly and with reasonable care will give many years of good service.

With the exception of electrotype metal, all the type metals must possess unusual casting properties. The term castability does not connote the full significance of the problem. There is first the ability to reproduce detail. Hand-casting operations were presumably much simpler technically than casting with modern high-speed machines. Yet even in hand casting it was soon realized that only the lead-tin-antimony alloys rich in lead would reproduce the necessary fine detail of small type, and that the composition of the alloy must be rather closely controlled. We increase the hardness of these alloys by increasing the amount of tin and antimony in them. Antimony alone would accomplish this but a roughly constant relation seems to exist between the amounts of these two substances.

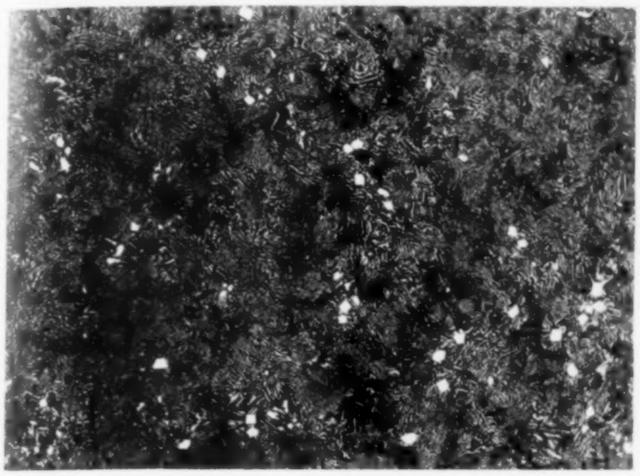


One Small Portion of a Monotype Indicates the Complexity of the Modern Casting Machine. Observe the molten pool of type metal in the central foreground

Ability to Reproduce Detail

From the discovery of movable metal type until very recently this superior detail-reproducing ability was explained by assuming that the antimony imparted its rare property of expanding during freezing to these alloys. This is absolutely incorrect. The exact volume change in type metal is roughly a function of the weighted averages of the volume change of the separate metals involved. Consequently the shrinkage is lowered somewhat by the minor percentage of antimony, but theoretically these alloys *should* shrink, as do practically all alloys, when they change from the liquid to the solid state. Actual determinations show them to shrink from 2.04% for stereotype metal (4.0% Sn, 11.75% Sb, 83.75% Pb, 0.5% Cu) to 2.61% for electrotype metal (4.0% Sn, 4.0% Sb, 92.0% Pb).

"Low surface tension of the molten metal" has recently been offered as an explanation. At present so few actual determinations of surface tension are available that it is impossible to determine the relative values by direct comparison. However, the surface tensions of several type metals have been measured and the results are as low or lower than the known values for other alloys. The only alloys known to have surface tensions as low are of lead and bismuth, and bismuth may be substituted for part of the tin and antimony without impairing the quality of the type metals. Some evidence is also derived from the fact that zinc, even in mere traces, will completely eliminate the ability of one of these alloys to cast into clean type, and the author has found that a trace of zinc will increase the surface tension of a linotype alloy by 163%, provided the alloy is subject to oxidation for about one minute. Using a different method which exposed the metal to the full oxidizing power of air for two or three seconds, the surface tension was increased 30%.

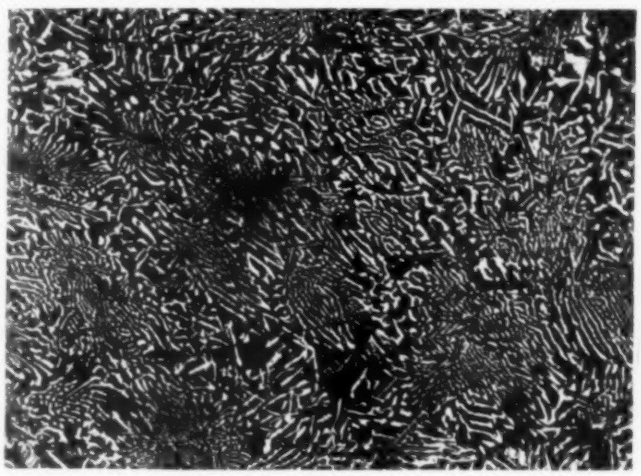


Linotype; Fine Eutectic, Slight Excess of Sn and Sb

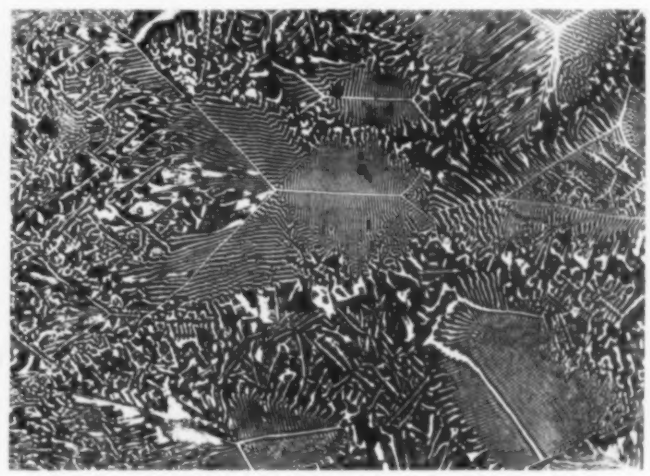
Medium-Hard Monotype; Containing Considerable SbSn

Type Metal, Chill Cast to Prevent Segregation; Structure at 100X Is Somewhat Coarser Than in Type

Linotype; Practically Eutectic Composition (350X)



The Two Eutectics in Slowly Cooled Type Metal (100X)



The thermal properties of these alloys in the liquid state may be important, but so little is known concerning thermal properties that it is impossible to state just what part they play. There are certain indications that they may be very important; certainly the quick-freezing characteristics of these alloys enable type casting machines to operate at very high speed. (A monotype machine may eject 180 finished castings per min.)

With the exception of foundry type which is used repeatedly, and some electrotypes which may be saved against the possibility of later reprinting in book work, practically all type is remelted after it has served its purpose on the press. This elevates several more properties of the type metals to positions of vital importance:

The low-melting characteristics of these alloys is a decided advantage in remelting, and of even more importance in the casting operations. The type-casting machines are truly precision-built instruments and higher temperatures would seriously complicate their construction. Again, the type metals all have freezing ranges, not freezing points, although in linotype metal the range is only a very few degrees and may be considered practically a point, 473° F. As the composition moves away from that of linotype metal in either direction the freezing range increases. Foundry type metal begins freezing at 620° F.; electrotype at 570° F.; monotype and stereotype at somewhat lower temperatures, (these figures being approximate, as they will vary with the composition). Regardless of the composition these alloys all finish freezing within one or two degrees of 473° F.

Chemical properties of the alloys as regards oxidation are very important in remelting old type and to a lesser extent in melting pigs in the casting machine pots, *(Continued on page 56)*

X-Ray Inspection

of high alloy castings

Results in an improved foundry product when the films are interpreted by one who knows the principles of radiography, and who has correlated such evidence with defects discovered on cutting castings apart and with the service records of inspected castings. Since sound metal presents films of no contrast, the illustrations are taken from defective castings occasionally found.

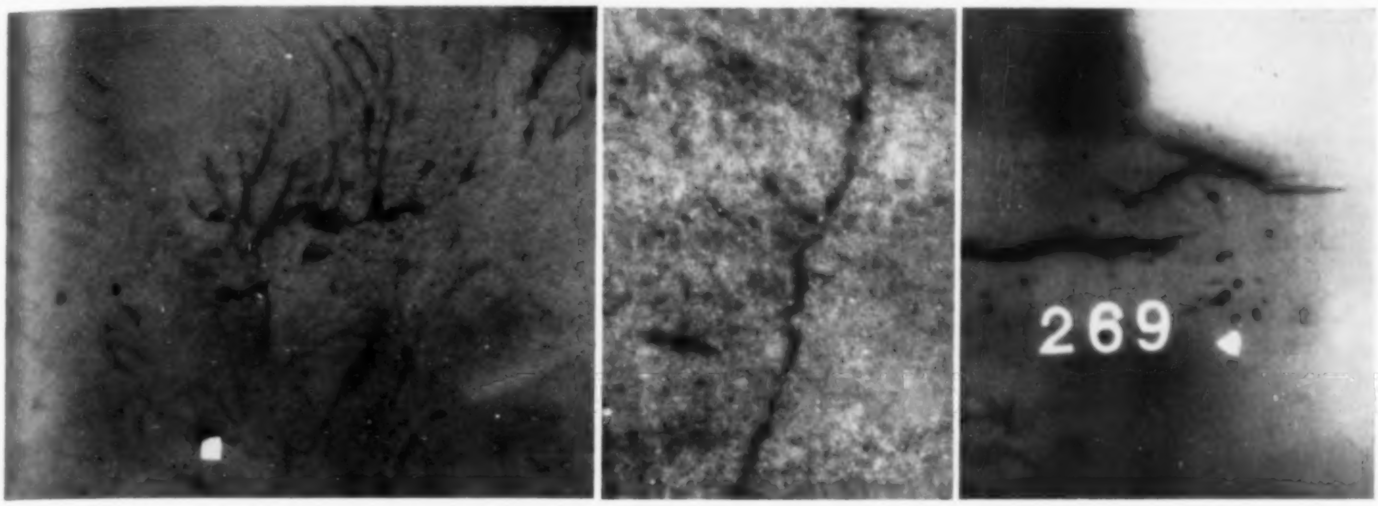
By F. K. Ziegler and D. W. Bowland
Metallurgical Engineer and Radiographer
The Electro-Alloys Company, Elyria, Ohio

USE of the X-ray in the inspection of metallic structures has increased to the point where almost anybody who buys or uses castings and welded objects must pass an opinion on the quality of one of these articles by examining an X-ray film or radiograph, or a print made from it on photographic paper. The film itself is considerably thicker, stiffer, and usually larger in area than an ordinary camera film. On first inspection it may look like a piece of light-struck film, badly over-exposed. It may have several spots, light or dark, of varying shapes and sizes, scattered over it, and it is sometimes embarrassing to have to admit that it looks a good deal like the sun over Pittsburgh on a foggy day! It is even more embarrassing to venture interpretation, and then to have someone with a knowledge of radiography prove that the deductions are all wrong.

The foundry company with which the writers are connected has adopted the X-ray apparatus as an integral part of its inspection of nickel-chromium castings for heat and corrosion resistant applications before shipment to users. During the past year a great many films have been mailed to its customers upon request; in such cases the radiographer's original report about the condition of the casting is enclosed without further comment. Naturally, no castings with harmful defects are shipped, but occasional misinterpretation of these films by the customer has led to the belief that a brief article showing how casting defects appear on a radiograph may prove interesting and helpful to many people in the metal industry.

Metallurgical knowledge of the properties of the nickel-chromium-iron series has developed rapidly during the past few years, and all progressive alloy manufacturers have determined upon compositions most suitable for common specific applications. Chiefly for this reason, technical men in the foundry industry have more time to devote to a study of methods for the production of better castings.

In the foundry the effects of changes in practice can be checked by one of two methods: (*a*) Complete destruction of the casting by sectioning at several points; (*b*) X-raying the casting. The first method has been used to a considerable extent in foundry investigations, but it is far inferior to a radiographic study, owing to the impossibility of breaking or cutting a casting so



Things in a Radiograph Which Look Like Cracks But May Not Be

Dark lines are cold shuts frequently present on surface of 1-in. castings of nickel-chromium alloys. They can be matched against visible markings on the same area. A few small blowholes are also visible; one directly at the lead marker. White spots are dust on film or paper.

This dark line results from a crack in the dry sand core or mold which has been covered up with a slight excess silica paste. It can be matched with a slight groove on the casting's surface.

True internal cracks alongside the rib on a retort, discovered by radiography. Associated surface marks were almost certain to be missed on visual inspection.

that any or all of its unknown internal defects become visible. Furthermore, large castings are seldom broken as a check on molding methods, due to the cost involved, and it is usually the larger castings which show the worse defects upon X-ray examination. Breaking up a casting is, of course, out of the question as a method of inspecting it; such destructive testing can only be used as a guide to better production methods. This leaves the X-ray and radium as the only means now known to show up internal defects.

Adoption of the X-ray is dependent upon the desire to ship no castings containing any major defects. In spite of the foundryman's efforts to make the best use of his experience in devising improved technique and standardizing his practice on the production of castings of simple or recurrent designs, he occasionally suffers the experience of having such castings fail in service. This is usually accepted as evidence that metal founding has never been reduced to a science; it probably will not be until our knowledge of the many variable factors is considerably greater than at present.

Even though manufacturing processes in the foundry could be made fool-proof, the alloy busiiess is of such a nature that standardization of practice is seldom possible. Outside of a few patterns which reappear regularly, the designs of castings vary so widely and are changed so often that the highest type of technique is necessary to produce good castings. On account of inability to control all factors of production, it is fortunate that we have, as a final check of visual inspection, a method which enables us to look through the casting and expose any foreign substances which do not belong there.

Amount of Work Necessary

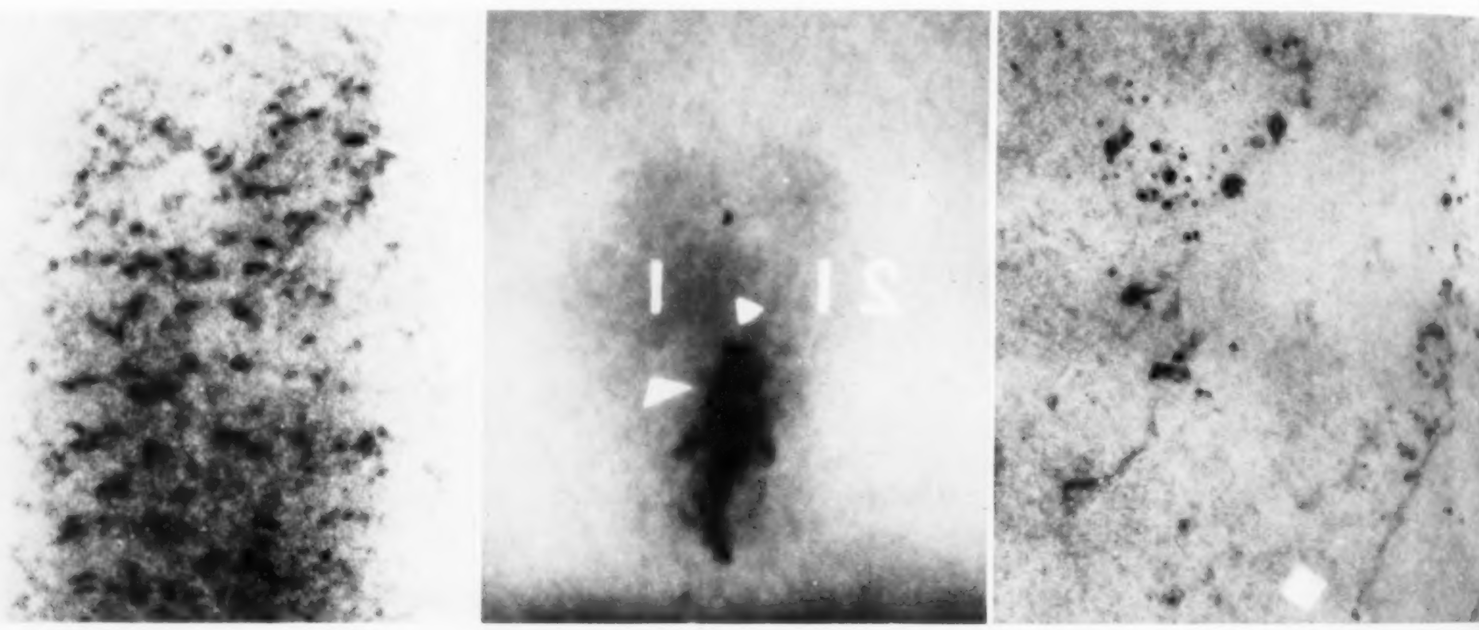
In regular production no attempt is made to X-ray every casting — obviously this would be impractical in an order for several hundred small parts. Such an order would be checked by radiographing a reasonable percentage picked at random. If any castings are found defective, all those from the same heat or made by the same molder are segregated and examined. This not only protects the customer but often enables us to determine the cause of the trouble.

Castings from all new patterns are X-rayed to determine whether the foundry practice is correct; when changes are necessary, their effects are rechecked. All pressure castings such as carburizing retorts, valves, fittings and pump parts, all containers for molten salts or lead, are

radiographed before shipment, as are practically all sizable castings at those points where defects would be most likely to occur.

In good foundry practice the casting is first subjected to careful visual inspection and any minor defect is repaired by welding (providing the casting is of such nature that welding will not interfere with its life in service). Radiographic inspection is then done by placing it in the lead-lined X-ray room and the operator chalks out areas upon it corresponding to the size of the film, and makes a sketch fixing the position of each. Lead numbers are placed on the outside of the cassette containing the film areas are subsequently X-rayed to determine whether the defect has been completely removed, and whether the weld is sound.

The developed films and the sketch showing their position on the casting are filed in a single envelope and in the event of subsequent failure, the original record may be closely studied in an effort to determine whether the cause could have been discovered. Some failures are to be expected, even with X-ray inspection, until experience enables the inspector to perfect his practice and to interpret the films correctly. These failures will disappear as familiarity with the method increases.



Internal Cavities of Various Sorts Discovered by X-Rays

Spongy regions are located in sections particularly difficult to feed with risers; they also occur in castings poured too hot. They consist of small shrinkage cavities distributed through a rather large volume.

Large shrinkage cavities can be looked for under a gate or riser improperly designed or placed. They can be eliminated by changing details of molding practice.

Blowholes are round, like bubbles, and are probably caused by some reaction between sand washed from the mold or core and the hot metal, releasing gas which normally would stay in solution.

for the double purpose of marking the film and of assuring that the rays have penetrated the casting. Other lead markers are placed on the chalk marks on the casting, to spot the film accurately.

These chalk marks are left on the casting until it is approved for shipment. Following the exposure and development of the film (by methods known to X-ray specialists, which are beside the scope of the present article) any defects brought to light are marked on the casting (which is not moved until all exposures on a given area are made and developed). All welded

Correct reading of the films is of vital importance. Much experience with a wide variety of films, correlated with evidence from sectioned castings, is required to recognize a true defect, gage its seriousness, and determine whether the casting can be safely shipped as is, repaired successfully, or whether it should be scrapped. A body of correlated information comes from service reports on radiographed castings. In view of the varied nature of this work, experience is the only teacher in the correct interpretation of X-ray films.

The use of the word "repair" in the fore-

going paragraphs is not meant to infer that treatment of defective spots necessarily results in an area inferior in physical or chemical properties to the original casting. Such an inference would not only be at variance with many years of service experience with correctly formulated alloys, but contrary to the metallurgy of austenitic alloys. The high nickel-chromium alloys subjected to the inspection methods described are austenitic in character; welds made with covered rods of the same composition with the parent metal and properly laid down have the structure of the main casting and require no heat treatment to bring out an equal resistance to heat and corrosion.

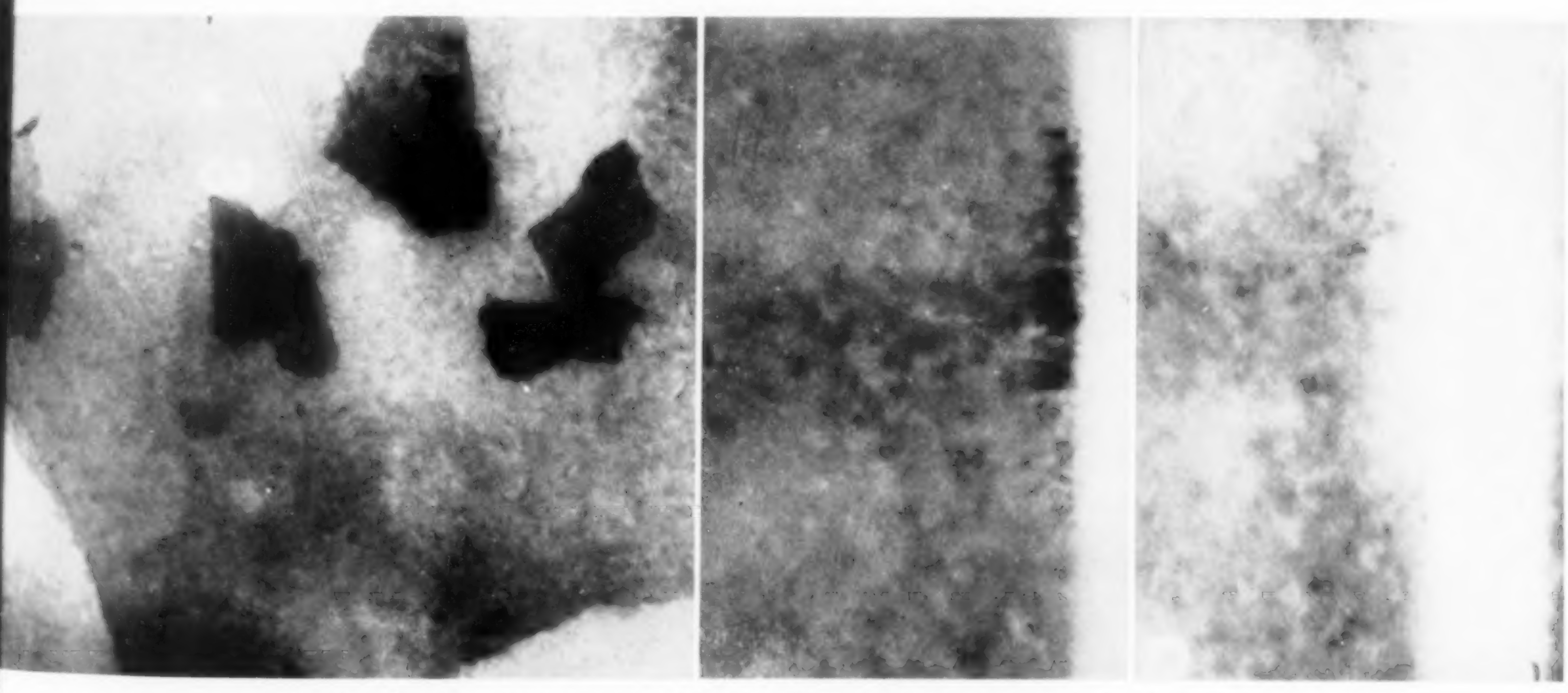
Naturally there is a practical limitation as to the size of an area that can be successfully and economically welded, and if defects are found which exceed such an area, the casting is scrapped forthwith. (One of the first astonishing results of the use of the X-ray is the size and extent of hidden imperfections shown by this method which are incapable of being found by any other means of inspection, but which may be readily corrected once the foundryman is aware of their presence.)

Illustrative Films

The accompanying halftones illustrate some defects found in castings made by ordinary commercial practice. These are negative prints and show black and white contrasts in the same manner that they are shown on the radiograph; in other words, denser portions are lighter, voids are dark. It is impossible to reproduce the same degree of contrast shown on the film; for this reason photographic prints of the film are only used where actual radiographs are not available for examination.

The castings were all of the nickel-chromium heat and corrosion resistant groups and in one of the following analyses: (*a*) 60% nickel, 15% chromium, (*b*) 38% nickel, 18% chromium, or (*c*) 29% chromium, 9% nickel.

It should be remembered that X-ray films of castings do not show the uniform density of those obtained from rolled sections, owing to



Sand Inclusions, Shrinks and Welds in High Nickel-Chromium Castings

Large sand inclusions (broken from the gate and entrapped in the metal) have characteristic grayish color, quite distinct from the dense black of a cavity. Light spots at corners are due to variable thickness of sound metal, due to a patch applied to a broken core.

Dark marks represent shrinkage at an area adjacent to a rib. This common defect on irregular castings is prevented by proper chills or risers. (The white strip on the print was under a rib so thick that practically no rays penetrated it.)

Same area as shown at left, after the casting has been cut into, down to sound metal, and the channel refilled with weld metal. Somewhat lighter gray in the print is due to a slight excess added by the welder.

the inherent variation in cross-section of cast products. Sound metal gives a film like the second halftone. Maximum sensitivity of the equipment is about 2% of the thickness of section being examined, and *average* sensitivity is approximately 5%. Practically all sand castings, particularly the larger sizes, have this difference in thickness as a natural variable (0.05 in. in a 1-in. wall) and they affect the opacity of the exposed and developed film, resulting in the characteristic uneven or cloudy appearance. Films exposed under a slightly curved section also are uneven in density.

This difference in density does not obscure real defects, which are visible whether the surrounding film is dark or light. Defects in the film itself, such as pin holes, scratches, and dust spots, are sometimes interpreted as defects in the casting, although they are so characteristic in appearance that one never need be misled.

Voids vs. Solids

Internal defects in castings are of two general types: (*a*) Voids, such as blowholes, shrinkage cavities and cracks, and (*b*) solids, such as sand and other non-metallic inclusions. A given thickness of solid metal absorbs X-rays uniformly, whereas both voids and non-metallics allow the rays to penetrate much further (although the relative action is in different degree for the different non-metallic and gaseous inclusions) and rays through such regions reach the film in greater quantity and intensity, thus causing darker spots to appear on the film when it is developed. Characteristic differences in the shape, density, and sharpness of outline enable the trained observer to determine the cause.

The second group of films showing cavities is a case in point. Irregular shrinkage cavities need not be confused with round blowholes. Blowholes as shown, due to reaction with sand particles, are different in shape from holes caused by immigrant mold gases; the effects of the latter are visible on the surface. Again, blowholes in "blowy" metal are present in much greater quantity and are always visible on riser necks when risers are removed.

In spite of the various forms of defects shown in this article, it is not our intention to leave the impression that all alloy castings are defective. Absolutely perfect castings are but rarely produced, but in a large percentage the defects are so slight that the useful life of the castings will not be materially affected. Service records on many castings, which were subjected to very careful visual inspection before shipment, have conclusively proved, however, that some forms of internal defects materially shorten their life. The proper use of the X-ray would undoubtedly have located these defects; and the correct interpretation of the radiographs will determine their bearing upon the life of the casting.

Use of radiography for final inspection causes everyone in the foundry to take greater care in the manufacture of the castings. If the molder knows that careless work on his part is going to be discovered, even though the effects of this carelessness are hidden to the eye, he will take every precaution known to him to avoid any irregularities in the finished product. Despite a number of opinions to the contrary, the writers feel that the love of craft is still present in most high class workmen. If their short-comings are called to their attention, they will do anything within reason to correct them. When they are shown the results of their efforts in the form of an actual picture of the inside of a casting, verified by the exhibition of a predicted internal defect when the casting is cut open, they acquire confidence in the method used in obtaining the picture, and welcome it as a means of showing definitely the quality of their work.

Penitent's Corner

The Editor has two errors to confess, one of omission and one of commission.

He carelessly omitted to mention that the excellent photographs of members in the last issue were snapped at the New York convention by Past-President W. B. Coleman.

Another mistake occurred in the creep-stress curves on page 54 of the big October issue. These curves were released for publication by the Calorizing Co. on the basis that the trade names would be used, but unfortunately this stipulation did not reach the Editor, or it did not penetrate his consciousness, else the curves would not have been used — it being the rule to avoid trade names in the text. We are also informed that the compositions quoted are in error, but the Calorizing Co. does not forward us the correct analysis.

Uniform Hardening

of large bearing races

An account of how a serious problem of hardening chromium steel rings without soft spots was solved. It was desired to utilize old furnaces and install a minimum of control. Success was achieved by regulating flow of both gas and air and working to program; rings were decarburized at very surface during heating and soaking, but just before quenching an excess of air scaled off this altered metal.

IN the regular production of ball and roller bearings in the SKF plant at Gothenburg, Sweden, gas-fired furnaces have been successfully used for hardening. Some troubles had been found with soft spots on rings for fairly large bearings, however, and the investigation to be described was therefore undertaken.

The furnaces used are under-fired hearth furnaces of moderate size such as shown in the half-tone on page 31, and had been used for a long time. Past experience indicated that electric furnaces were not suitable unless filled with a controlled atmosphere. Molten salt had given good results, but it cost too much. An inexpensive alteration of existing equipment or its method of operation was the desired solution.

According to the old heating method, which had been used for about two decades, the inner rings for ball bearings were heated direct to quenching temperature in the shortest possible time without risking overheating; in order to heat evenly, they were turned from time to time. It was then, of course, necessary to open the furnace door. The air valve on the fuel system was always wide open; regulation was entirely with the gas valve.

by Bengt Kjerrman
Chief of Laboratory; SKF
Gothenburg, Sweden
and Ivar Bohm
Deputy Professor,
Technical University, Stockholm

The first diagram shows the conditions as existing in an average heat. For the first 45 min. the air-gas mixture was fairly suitable (in the light of our later investigation) in spite of the fact that a liberal quantity of air was sucked in all the burner ports below the furnace hearth. At the very end of the heating-up period the gas valve was throttled temporarily and gradually reopened; therefore during the entire equalizing period (called "soaking period" on the diagram) there was always a surplus of air.

Metal used in these parts contained about 1.0% carbon, 1.5% chromium, 0.3% manganese, and 0.3% silicon, and was made by the Hofors steel works. Quenching was done in mineral oil at 125 to 140° F.

After the rings had been removed from the oil they were inspected and tested with a file. For the purposes of this test the color and hardness of the surface as well as the existence of soft spots were noted. After grinding the track and etching with 7.5% nitric acid in alcohol for about 5 min. the surface was examined for troostite spots. The hardness of such spots and of the tracks as a whole was determined with the scleroscope.

After this inspection one or several rings were selected, and a cross-section was ground on each ring through a portion free from spots, and examined under the microscope.

Briefly, the problem was to devise some simple method of hardening the rather large rings in question without soft spots, cracks, or coarsened structure. From theoretical considerations it would appear that the ability to harden a given shape of steel into a fully martensitic structure depends on five factors:

1. *The chemical composition of the steel.* The critical cooling rate is different for different compositions. A low critical cooling rate means that the steel will harden more easily and more deeply. Manganese is the cheapest alloying element for this purpose and perhaps the most used.

2. *The structure prior to hardening* is of fairly little influence. A rolled, unannealed material is easier to harden than the same material soft annealed.

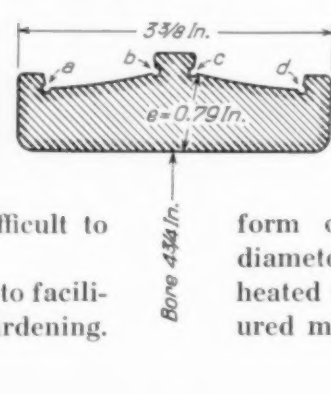
3. *The surface treatment.* This refers to the treatment prior to as well as during heating. In this connection one may distinguish between mechanical surface treatment and chemical surface treatment. Hardening will only be slightly influenced, but if surface treatment is the only factor that can be varied, its influence may be of decisive importance.

4. *The hardening temperature.* Broadly speaking, it is very difficult to increase the hardening effect by varying the hardening temperature. A certain grain structure is usually desired and this stands in close connection to a definite hardening temperature (given constant thickness of material, quenching medium, and other conditions).

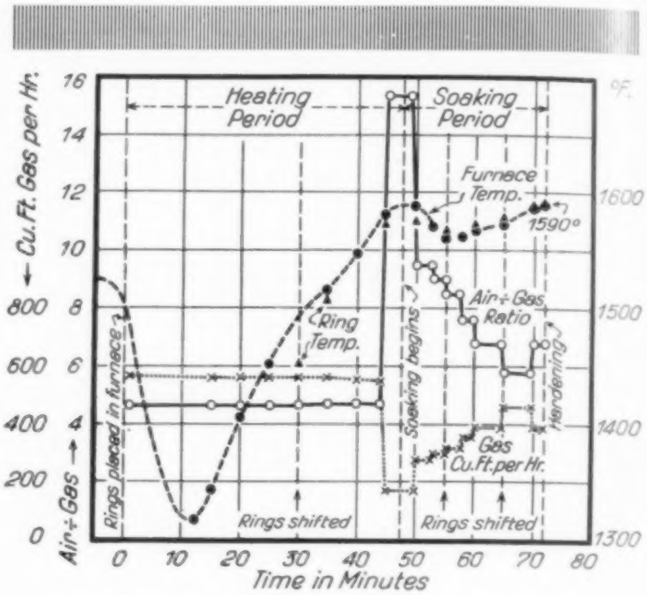
5. *The quenching medium.* Water, oil, air, brine, or lead bath are used and appreciably influence the results. A powerful cooling medium is often undesirable because of the risk of cracking the steel.

The shape of the rings to be quenched was decided by considerations out of the control of the metallurgical department, and was of the cross section shown. The dimension *e* is the one which determines the difficulty of hardening. This type was chosen as test pieces because they are very difficult to harden in oil.

Cross-Section of Inner Ring Under Test. Races between a and b and c and d could not be hardened in oil without developing soft surface spots



Relief grooves at *a*, *b*, *c*, and *d* are to facilitate grinding the race tracks after hardening.



Log Chart of Furnace as Operated Prior to This Investigation, Which Produced Bearing Races With Unsatisfactorily Hardened Surfaces

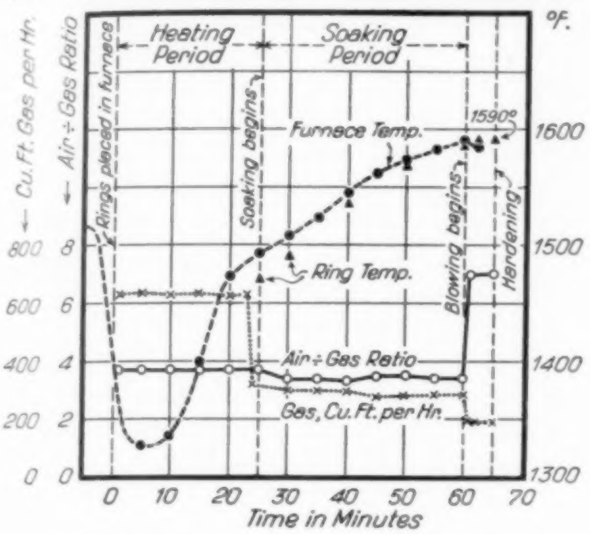
These grooves increase to a high degree the hardening difficulties already offered by the presence of the upstanding flanges.

Such rings cannot be water quenched in the ordinary way, since hardening cracks would always develop at the relief grooves. On the other hand when hardening in oil the risk of soft spots is very great, when ordinary high chromium ball bearing steel is used, as soon as the material exceeds ⅝ in. in thickness.

This ring therefore could not be hardened satisfactorily in oil according to our old methods, but it was not so far outside the limit of what was possible that it might not be done successfully if a suitable surface treatment or surface condition could be discovered.

It would appear that about all we could do would be to prepare the surface of the hot steel so it would transmit heat to the oil at the maximum uniform rate. A preliminary investigation was therefore undertaken to determine the action of various gas-air mixtures on the steel at preheating and soaking temperatures.

For this purpose some test pieces were prepared in the form of polished cylinders about ⅜ in. diameter. They were enclosed in a pipe and heated in an electric tube furnace. A measured mixture of air and gas was introduced



To Harden Rings Properly the Atmosphere Was Slightly Reducing Until 5 Min. Before Quenching, When an Excess of Air Was Admitted to Scale Off the Thin Decarburized Skin

in the glowing part of the pipe by a small quartz tube containing an asbestos plug, in which the combustion of the gas takes place. The test pieces, therefore, came only in contact with the products of combustion.

The gas contained large quantities of hydrogen as can be seen by the following analysis (by volume): CO, 12.6%; H_2, 50.6%; CH_4, 22.6%; C_2H_4, 2.9%; CO_2, 3.2%; O_2, 0.5%; N_2, 7.6%. Its products of combustion contain much water vapor, which explains in part some of the apparent anomalies encountered.

Test pieces were held for 60 min. at temperature and then cooled in air. Decarburization was noted on a microsection, and amount of scale measured by pickling in an inhibited sulphuric acid solution and then determining the loss in weight.

At 1400° F. (representative of the preheating period during actual heat treating) it was found that a slow gas current would decarburize the samples as much as 0.04 mm. deep if the air to gas ratio varied from zero to 7. If more air (or all air) was used, there was no decarburization. In more rapid gas current the transition occurred at 5 volumes of air to 1 of gas.

At 1580° F., the quenching temperature, samples were decarburized as much as 0.18 mm. in slow currents of all mixtures ranging from pure gas to pure air. More rapid currents decarburized the test pieces if the air-gas mixture was richer in gas than 9 of air to 1 of gas, but when more air than that was present, there was no decarburization.

The above results must not be interpreted to mean that there was no scaling of these samples. In fact, with nothing but air going through the tube, the oxidizing action will be so strong that the iron and carbon both combine at the same speed and beneath the scale will be steel without decarburized surface. If, on the other hand, there is sufficient gas in the mixture, it will protect iron better than carbon, and there will be a decarburized surface under the scale. As to the amount of this scale, the pickling operation indicated that it was very slight after periods of one hour at heat — for instance, amounting to only 0.01 mm. in pure air at 1400° F. and the same in 4 air to 1 gas at 1580° F.

From our results we discovered that by heating in pure air an essentially stronger oxidizing layer will be formed than by heating in a gas mixture, but there will be no decarburization. It is, however, clear that such conditions might occur (through temperature variations or alteration of the gas speed) that a certain decarburization may occur even in pure air, as has also been observed in other tests — but broadly speaking it might be said that the richer the gas mixture (within the limits here investigated) the more efficiently decarburizing but the less oxidizing it will be.

Since soft spots on the surface might readily be due to a deficiency of carbon, it appeared logical to search for some combination of heating atmospheres which would insure a surface free from decarburization, even if it were scaled more or less. Hence a series of tests was next carried out in the plant, using full-sized rings and standard equipment.

The routine was as follows: Rings were placed in the furnace when this had reached a temperature of about 1500° F. The temperature of the furnace naturally fell somewhat, so that it took from 13 to 32 min. to come back. Rings were generally kept at 1500° for 10 min., the first soaking period, whereupon the temperature was increased to 1580° F., this requiring a period of from 6 to 19 min. The second soaking period at 1580° F. required from 2 to 13 min., whereupon the rigs were quenched.

Such tests were carried out with different mixtures of air and gas. Since the furnace had no measuring arrangements, it was only possible to determine whether there was a surplus of gas or air in the furnace from the character of the flame. The results can be summarized in the following manner:

Rings heated with a surplus of air during the whole period showed the poorest result. On the other hand, those which had been treated with surplus gas up to

the last soaking period and with surplus air just before quenching gave incomparably the best result. This last "blowing-through" period must not be chosen too short; about 10 min. seemed to be correct.

If these results are considered against the background of the laboratory tests, it is apparent that the best hardening will result if a reducing atmosphere is maintained during the greater part of the heating. Formation of scale during this period will be relatively slight. It is not recommended to harden the surface then existing — that is, a surface which is practically without any scale, yet slightly decarburized. By means of a "blowing-through" action, when a large excess of air is in the furnace, a relatively thin layer of scale will be formed corresponding to the previously decarburized surface layer. This thin layer of oxide is brittle and easily falls off in quenching. Thus the hardening results will be satisfactory.

A 5-In. Bearing Ring, Improperly Hardened. After cleaning off scale and dipping in nitric acid, troostite (soft) spots appear as dark, cloudy areas

Final Adjustments

It then remains to translate these findings into actual plant practice. One of the regular furnaces was repaired to reduce the influx of outside air and various meters and pyrometers were installed. Gases were sampled and analyzed. New valves were placed in the lines so gas and air supply could be independently adjusted, and the pressure of the mixture measured by a water manometer.

Such experiments acquired a great deal of information which cannot be reproduced in small space. One practical fact is that a comparison for figures for "unpacked" and "packed" burner ports shows that the undue air in the former case corresponds to an air surplus of 10 to 15%. The tests furthermore showed the importance of keeping the furnace well filled with combustion gases, since otherwise air can easily gain access to it. Particularly during the soaking period it is important that the gas be not throttled too much if intended reducing conditions are maintained.

Since we had demonstrated that the flow of gas past hot steel affects the surface reactions, it was necessary to control the volume of gas-air mixture as well as its proportions. The latter can be closely adjusted by eye — that is, as to surplus gas and air. The volume is proportional to the manometer reading and after sufficient experience has been gained the furnace can be operated with an empirically graduated manometer and a pyrometer.

The second record sheet (top of page 29) shows average conditions existing in such a furnace, properly operated.

It will be observed that a reducing flame is used and a large volume of gas is burned during the first 25 min. when the rings are coming up to heat. Then the volume of gas-air mixture is sharply reduced for a 35-min. soaking period, during which the furnace and the rings creep up from about 1450° F. to 1575° F. At this time the air is increased so a strongly oxidizing condition exists in the furnace, and in 5 min. the rings are ready for quenching.

Under these conditions all the rings, after grinding, were entirely free from soft spots, showing a scleroscope hardness between 90 and 95, corresponding to Brinell of about 670.

Corrected Practice Saved Fuel

If these two hardening practices illustrated by the diagrams are compared, one will first be astonished by the great difference in the last part of the heat. In the revised heating period a ratio 7 air to 1 gas exists at the very end. In the old practice a ratio of more than 15 to 1 existed at the beginning of the soaking period. It would perhaps be anticipated that the gas consumption of the revised practice would be greater than before, when, practically speaking, there had been a surplus of air all the time. This, however, is not the case. The total gas consumption for 65 min. is now 430 cu.ft. whereas it used to be 600 cu.ft. per heat. This is, of course, ex-

plained by the fact that the excess air in the old practice used heat without giving anything of value in return.

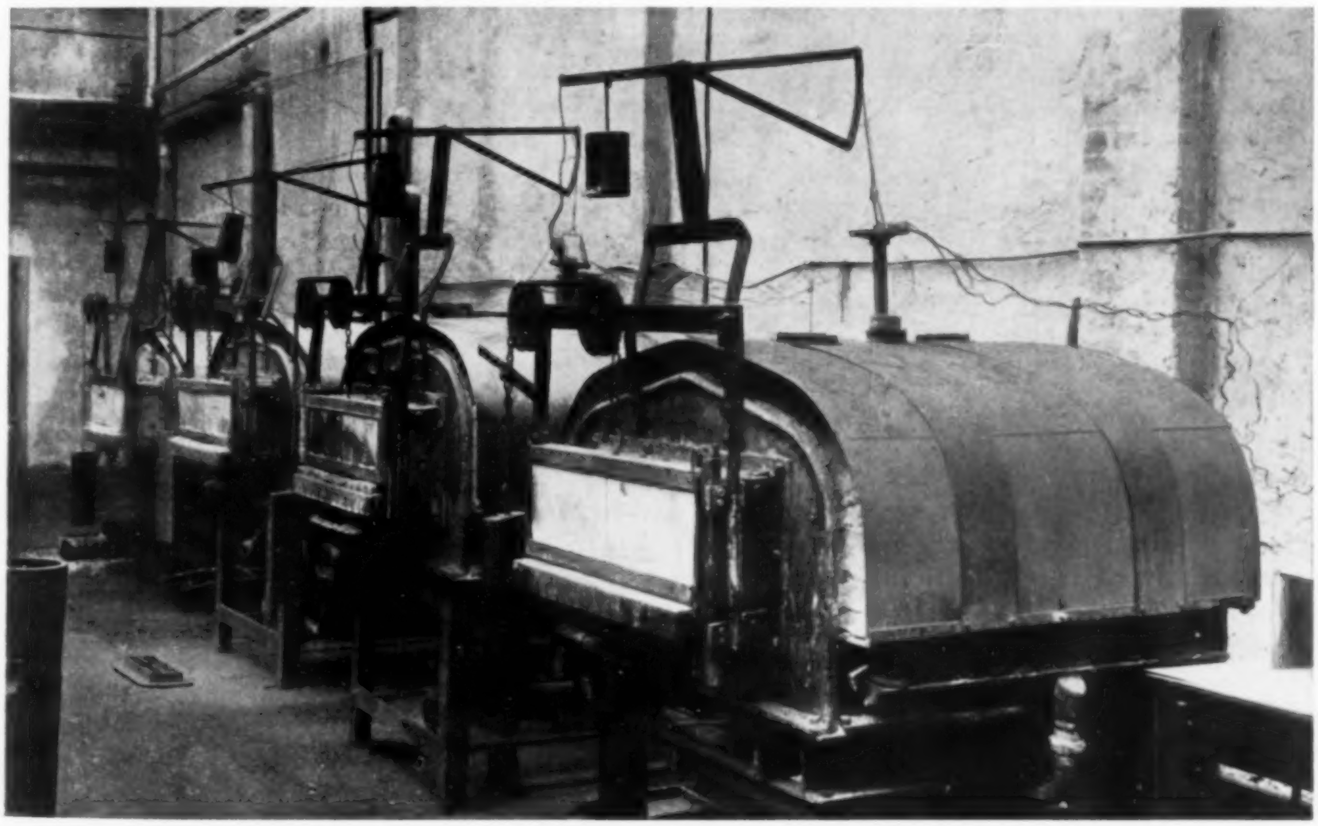
Microscopical investigations showed considerably different quantities of troostite, measured on the previously mentioned cross-sections. Measurements were made immediately below the race tracks, partly at the two outer flanges and partly on both sides of the middle flange. At the middle flange the quantity of troostite after a revised heating period was 5% and at the outer flanges 2%. For former practice it was 15% at the middle flange and 5% at the outer flanges.

Application To Continuous Furnaces

Thus the investigation has shown that simply by altering the atmospheric conditions during heating it is possible to influence the results obtained after quenching. It has been ascertained that the ratio of air to gas as well as the quantity of gas is of decisive importance, particularly at temperatures exceeding about 1500° F. for the high carbon high chromium steel in question.

All these experiments have been carried out using an old type of furnace, heated underneath the hearth. Our more modern furnaces are overfired with surface combustion burners. It was thus very essential to determine if the new conditions hold in these modern furnaces, especially those working continuously.

In our factory this was done with a roller hearth furnace having a length of 19 ft. A reducing atmosphere was kept in the charging end and the part where the soaking occurred was worked with an air surplus. Results were very satisfactory. It is very essential that the furnace be long enough, which we would emphasize, because many of them do not need this length merely for heating purposes. However, this is not the only advantage gained by length. The output increases very much with the length, and thus there are good reasons for making the furnaces longer.



The Problem Was to Revise the Method of Operating These Old Semi-Muffled Furnaces so Large Roller Bearings Could Be Hardened Without Soft Spots. It was solved by closing all openings where excess air was entering, burning fixed proportions of air and gas according to a definite time schedule and controlling the volume of the fuel by a manometer

Aluminum Cap Piece

on Washington monument

To prevent damage by lightning, the builders of Washington Monument placed a small pyramid of aluminum, properly grounded, at the very top. Recent inspection showed the metal to have withstood 50 years' exposure perfectly; aside from some marks left by lightning strokes, no damage is discernible. Surface oxide has not obliterated the finely engraved inscriptions

THE crown jewel of the aluminum industry is the cap of the Washington Monument.

At one time it was considered as jewelry not only by the metal industry, but also by the public at large, for prior to its setting on December 6, 1884, it was displayed in the windows of Tiffany's, New York, as the largest casting of aluminum ever made. The then precious metal sold for $1.10 an ounce, almost double the price of silver. Today it sells for 21¢ a pound!

The reasons for choosing aluminum to top the monument had been forgotten years ago. Some thought that it was just a reckless impulse on the part of government engineers. But according to correspondence discovered only a few weeks ago in a cubicle at the base of the monument, officials had a very good reason for their choice of metal.

Col. Thomas L. Casey, the Army engineer in charge of construction, submitted a report to the Washington Monument Commission in September, 1884, in which he proposed to make the tip of phosphor bronze, but added he would like to have one made of an aluminum alloy. He was afraid, however, that aluminum was available only in France and to buy it there, he reasoned, would make the cost prohibitive.

by E. H. Dix, Jr.
Chief Metallurgist
Aluminum Research Laboratories
New Kensington, Pa.

Another letter was written by Col. William Frishmuth (who operated a foundry at Rush and Amber St., Philadelphia) to Col. Casey in October, 1884, suggesting the use of an all-aluminum cap since aluminum was an excellent conductor of electricity. Col. Casey commissioned him to proceed with the casting. (The tip, it may be noted, was to serve as a lightning rod. Extra precautions were to be taken because the lower portion of the monument had been seriously damaged by lightning in the 25 years it had stood uncompleted.)

That Frishmuth had his fears in regard to successful aluminum foundry work was shown by a later letter, in which he advised Col. Casey that he was casting a pure aluminum cap and an aluminum-bronze cap, to insure the casting of one cap that would prove acceptable.

The original invoice for the work amounted to $256.40, but Capt. George W. Davis, one of Col. Casey's assistants, protested that the amount was too high for the 100-oz. casting, and itemized charges which in his opinion were excessive. The original invoice is not among the documents found in the cubicle, but there is a voucher from Frishmuth to Col. Casey acknowledging receipt of $225, representing full payment for the

work done on the cap. This figure indicates that Capt. Davis's report on excessive charges resulted in either the elimination or the reduction of certain of the original charges.

The cap was polished and then sent to New York, where it was displayed in Tiffany's windows. On December 6, 1884, the cap was set in place. Frishmuth asked Col. Casey to have someone take a chamois skin and wipe the pyramid well so that it would not show fingermarks! Such is the pride of workmanship.

The aluminum in the cap was made of South Carolina corundum — where or by whom does not appear, although the process was doubtless the one devised in 1854 by Sainte-Claire Deville, wherein aluminum-sodium chloride, fluorspar, and ingot sodium were heated in a reverberatory furnace and the liquid aluminum and slag tapped. (The present electrolytic method was not invented by Hall until 1886.)

One of the letters in the batch of documents discovered was written by an engineer, a friend of Col. Casey's, who belittled the newspaper accounts of the monument, which did not give proper emphasis to the use of aluminum in the cap. Aluminum, the writer predicted, would revolutionize the metallurgical art!

Engineering attention has again been directed to the monument, since the Government recently appropriated $100,000 to the National Park Service for a general reconditioning of the shaft.

Government engineers, metallurgists, and officials of Aluminum Co. of America were naturally interested to see how the cap had weathered the elements of 50 years. In what condition is it now? The answer would shed a great light on the future behavior to be expected of the millions of pounds of aluminum now used in architectural work the country over.

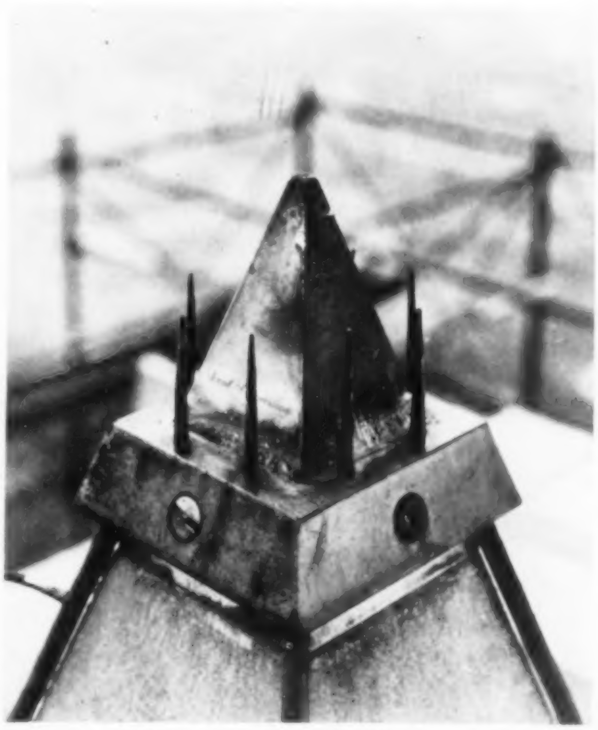
Information on the weathering of aluminum for a period of 40 years is already available. Inspection of the statue of Eros, erected in Piccadilly Circus, London, in 1893, showed that aluminum has stood up perfectly well in the industrial atmosphere of that great city. But with scaffolding going to the very top of Washington Monument came a chance to inspect a piece of aluminum ten years older than the famous English statue.

A party of scientists therefore ascended the spidery scaffolding to make an inspection 555 ft. above ground. The group is shown in the view on the next page, crowded on a platform about the peak of the monument.

All of us who examined the 100-oz. pyramid found its condition excellent. One of the things which cannot be seen from the ground, and which had hence been forgotten, was the band of gold-plated copper surrounding the pyramid and fastened by four large set screws, one in each face. From the corners of the band lightning rods (gold-plated copper tubes) extend down the sides of the pyramidal cap, a stone weighing 3300 lb., ultimately to connect with the iron stairway inside the monument.

Prongs of gold-plated copper project vertically upward from the top of this band, two to a side, and three similar prongs originally projected at right angles from each copper tube, one at the head, one in the center, and one at the lower end. Two can be seen in the view on the next page, but some have disappeared. These prongs are said to have been platinum-tipped. The plating has peeled in a number of areas and portions of the plating on the copper band were darkened and tarnished.

The apex of the aluminum pyramid has been blunted — fused from having been struck by lightning. The four inclined surfaces, exposed above the gold-plated copper band,



Cap of the Washington Monument Is an Aluminum Pyramid. Lightning arresters consist of a copper band, several points, and four tubes running down the capstone (all gold plated to avoid discoloration of adjoining masonry). Photo by Horydczak

Engineers and Metallurgists Examining the Tip of the Washington Monument: William W. Greig at Left, Construction Engineer, National Park Service; William H. Hunton and Ned Morris, Aluminum Co. of America; W. H. Mutchler, Metallurgist, Bureau of Standards; E. H. Dix, Jr., Chief Metallurgist, Aluminum Research Laboratories, New Kensington, Pa.; and H. S. Rawdon, Chief Metallurgist, Bureau of Standards. Photo by Horydczak

had taken on an oxide coating, uniform and very thin, so that a slight scraping with a knife and emery paper restored the original surface. Of course, the polish which had been put on at the Frishmuth foundry, and the chamois buffing after erection, had long ago disappeared!

Where the aluminum extends below the gold-plated copper band some slight pitting was observed under a magnifying glass, evidently the result of electrolytic action between the dissimilar metals. No pitting whatsoever was observed above the band, although the aluminum was slightly stained near by from the splash of rain which had caromed from the top of the band.

These visual observations were later confirmed by spectrographic analyses of a very small amount of metal scraped from the surface of the pyramid, both above the gold-plated band and below it.

The material scraped off the surface above the gold-plated band shows only a trace of gold; in other respects this surface product is very similar to the metal globules described below. The sample scraped from the surface below the band shows the presence of copper, iron, calcium, silicon, chromium, titanium, and a small amount of gold. It is estimated that several per cent of copper is present, and the amount of gold, though small, is greater than that found in the surface material taken from above the band.

Several globules of aluminum, fused to the sides of the pyramid after the apex had been struck by lightning, were removed for examination and for microscopic studies. About 1/40th of a gram used for spectrographic analysis of the metal was found to contain: Iron, 1.00%; silicon, 0.75%; manganese, 0.30%; copper, 0.05%; tin, 0.02%; sodium, 0.01% and aluminum, 97.87% (by difference).

That the aluminum was practically unattacked is substantiated by the fact that the inscriptions engraved on the four sides of the cap could be easily read by merely removing the oxide surface with a very fine emery cloth. Though the engraving was very light, the surface had not eroded. The complete inscriptions were not visible because of the copper band (which was not removed) but records show that they are:

On the North Side:

Joint Commission at Setting of Capstone, Chester A. Arthur, W. W. Corcoran (chairman), M. E. Bell, Edward Clark, John Newton; Act of August 2, 1876

On the West Side:

Cornerstone Laid on Bed of Foundation July 4, 1848; First Stone at Height of 152 Feet, Laid August 7, 1880. Capstone Set December 6, 1884

On the South Side:

Chief Engineer and Architect, Thomas Lincoln Casey, Colonel, Corps of Engineers; Assistants, Capt. George W. Davis, 14th U.S. Infantry; Bernard R. Green, Civil Engineer; Master Mechanic, Peter F. McLaughlin

On the East Side:

Laus Deo

The monument was originally started by popular subscription in 1848, but work was halted by lack of funds after the shaft had reached a height of 152 ft. This unsightly column became an eyesore and the butt of architectural jokes until Congress ordered its foundations reinforced and the shaft completed, by the Act passed in 1876. The line of demarcation is clearly seen in the monument; although the monument is faced with Maryland marble, the texture and color of the lower portion are considerably different from the upper part.

When finally completed, it was the tallest building in the world and has always been a sight toward which tourists gravitate. But for some years this famous shaft has needed repairs, and accordingly the National Park Service was authorized to undertake this task in 1934. The scaffolding surrounding the monument for this repair job is the tallest ever erected, and is a skeleton of pipe lengths, bolted together with cast fittings at intersections.

Flame Machining

its effect on steel

Important developments have been made in equipment and methods for oxy-acetylene cutting. Machines for cutting through or only partly through steel, following any line and at any angle are available. Hand equipment for deseaming billets is fast and economical. Extensive experiments show that structural and low carbon steels are uninjured along the cut surfaces for any further mechanical or welding operation.

REMARKABLE advances in the welding art were summarized in two articles in the October issue of METAL PROGRESS. It seems desirable, in order to round out the subject, to present a similar review of the present status of cutting and machining with the oxy-acetylene flame. This has always been considered a cognate branch of the industry, not only because the same gases and similar equipment are used, but because the economy of many welded fabrications depends upon easily cut intricate shapes.

It was fitting, therefore, that the first meeting at the 35th Convention of International Acetylene Association, held in Pittsburgh last month, was devoted to cutting. Particular reference was made to steel mill uses; aside from innumerable emergency and repair operations, tribute was paid by operating executives to five important applications where reliability and quality are equally as important as saving in time and money. Three of them are comparatively well known: Opening of blast furnace iron notches, tapping open-hearth furnaces, and cutting heavy cobbles in the rolling mills. Another (the cutting of wing-type ingots) was described by L. Gerald Firth and L. B. Knox, president and superintendent of melting department, respectively, of Firth-Sterling Steel Co. The fifth (deseaming of billets) was mentioned in discussion.

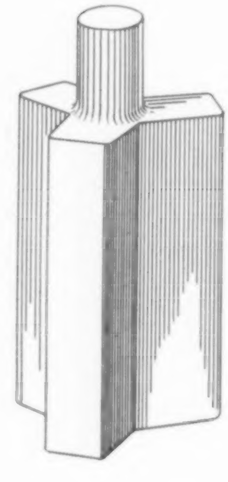
by Ernest E. Thum
Editor, Metal Progress
Cleveland, Ohio

Wing-type ingots (whose cross-section is sketched on the next page) were invented in order to place the segregated and piped regions in a portion which could be removed entirely, even though deep seated in the central axis. When the wings are cut off along lines indicated to form three ingots for forging and rolling, the central triangle can be scrapped or made into second-quality material.

Such an invention, of course, will stand or fall upon some economical method of cutting these heavy sections, and this the oxy-acetylene flame provides. Ingots are cut immediately after stripping, when the temperature ranges from 1400 to 1550°. Lower temperatures are associated with slight surface cracking in the high carbon tool steels and alloy steels manufactured, whereas higher temperatures mean rough cuts. Under these conditions costs are about as shown in the table at top of next page.

Total cutting costs come to about $1.60 per ton of wings sent to the rolling mill, and this is regarded as insurance well paid for sound material. Average discard,

center triangle plus cutting loss, comes to about 18% of the ingot weight — again a good figure for a tool steel mill — and this discard is taken immediately so no rolling expense is wasted on it. Mr. Firth said this type of ingot was being extended to the mill's entire production. The flame cuts all of the alloys except stainless, high speed, and high tungsten steels.



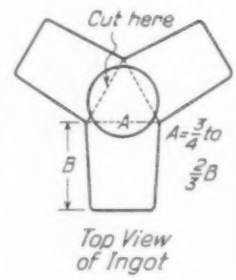
Being a producer of quality steels of tool and alloy grades, the Firth-Sterling Co. naturally investigated carefully the problem of damage by the cutting flame. "The most careful tests have failed to disclose the slightest difference in structure either in the annealed or hardened state due to the action of the torch," said Mr. Firth. "Apparently the effect of the gas and heat is extremely local and does not penetrate more than a few thousandths. Any surface effect that there may be is entirely eliminated by the scaling during cogging and finishing."

This same point — effect of flame on cut surfaces — was discussed at length by two other speakers at the meeting. One might think that the fact had already been sufficiently established that low and medium carbon steel can be cut with impunity; nevertheless, restrictions are continually being written into structural specifications and questions continually arising about its permissibility in class A welding.

Effect of Flame on Surface

An extensive investigation on this problem has just been completed at Massachusetts Institute of Technology, and was described by Prof. J. H. Zimmerman. A lot of ½-in. structural steel plate was secured from a warehouse and found to meet the A.S.T.M. specifications quite completely. Numerous cuts were made across these plates by five methods — milling machine, cold shear, friction saw, hand operated and machine controlled oxy-acetylene blowpipes. Various mechanical test pieces were then prepared where these surfaces were placed in the critical location — that is, on the outside of a bend test or impact test, and so on.

Data on Cutting Wing Type Ingots



	10,300-Lb. Ingot	335[illegible]
Center discard	1427 lb.	522[illegible]
Cutting loss (slag)	355 lb.	120[illegible]
Size, each wing	16x12x58 in.	12x9¾[illegible]
Time cutting each wing	7 min.	3[illegible]
Total time, including set-up	50 min.	20[illegible]
Oxygen per ingot	549 cu.ft.	165[illegible]
Acetylene per ingot	42 cu.ft.	16.5[illegible]

Penetration of hardness was studied on taper-ground surfaces.

Surface hardening was most intense in the friction-cut surfaces. Next came the sheared surfaces, hardened by cold work. Hardening of flame-cut surfaces was very mild and superficial. In the bend test, the surfaces cut with machine operated blowpipe were slightly superior to the milled surfaces, and those cut by hand only slightly inferior. In impact the order was reversed. Microscopic studies indicated that the pearlitic areas had been recrystallized near the cut to fine sorbite — a very tough constituent.

The complete evidence accumulated by Prof. Zimmerman would require several pages to present; his net conclusion is that surfaces cut with an oxy-acetylene flame in structural steel sections of usual thickness are damaged in no way. C. W. Obert, honorary secretary of the Boiler Code Committee of the American Society of Mechanical Engineers, stressed the fact that there was nothing in the code which frowned upon flame cutting preliminary to welding, although gas cut edges may not be caulked (a mistaken restriction, in the light of Prof. Zimmerman's investigations).

An associated problem is whether the tenacious but very thin layer of oxide should be sandblasted off before welding (of course, any lightly adherent oxide or slag in the kerf is brushed out). Some constructors require that the weld surface, if flame cut, shall be metal bright, but few of them would hesitate to weld on a rusted machined surface. Mr. Obert believes that the ability of all successful fusion welding processes to eject incidental amounts of oxide from the weld metal is sufficient to take care of these minor contaminations. His belief is based on tests made on joints made on metal-bright surfaces and identical ones made on flame-cut surfaces. Tensile tests, free bend tests, nick-break tests, and X-ray films show them to be equally free of defects.

Cutting Machines

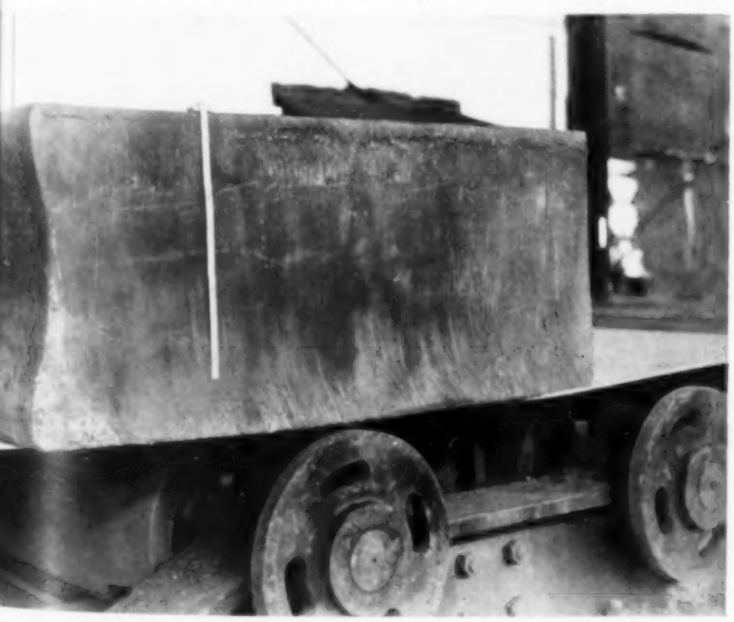
This matter of cutting steel plates, beams, and slabs has become so important to the metal fabricator that some mention of modern developments in equipment should be made. Many of these machines were on display and in operation at the National Metal Exposition held in New York in October, improved in design and construction for greater accuracy, portability, and range or reach.

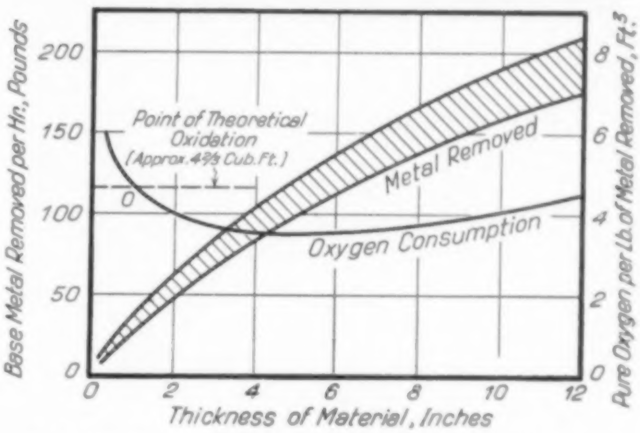
First should be mentioned the cutting torch itself. It has been refined so that it is able to make vertical cuts in heavy slabs with surprisingly low oxygen pressure — for instance, 40 lb. for a 24-in. steel slab, a pressure which would be about right for 2-in. steel in the equipment of five years ago. Figures for gas consumption have also been acquired in the diagram.

As is doubtless well known, automatic or semi-automatic cutting machines consist essentially of a well-designed cutting blowpipe or torch (with adequate pressure regulators for oxygen and acetylene), a motorized carriage, and some device which causes the blowpipe to follow any desired line. Since there are many mechanical methods of reproducing motion, there are many varieties of cutting machines utilizing these principles.

The simplest is a little carriage with driven

Smooth, Straight Cut Through Slab 22 In. Thick at Lukens Steel Co. As shown by extensive tests at Boston Tech, surfaces of structural steel cut with oxy-acetylene flame have mechanical properties comparable to milled surfaces





Relation Between Oxygen Consumption, Metal Removed, and Thickness in Normal or Line Cutting

wheels, arranged to move along a straight bar or beam, either by a hand wheel or by electric motor. Of course, such a device can be made into a circle-cutting machine by attaching a radius bar and fixing the center. Or it can execute sinuous curves by making appropriate bends in the guiding track. Likewise, the blowpipe can be tilted at an angle, so that in addition to the normal 90° cut, the edge may be beveled to any desired angle up to 45°. Portable cutting machines of this sort weighing about 40 lb. are now available. Straight-line cutting machines, mounted on a permanent frame so as to travel along the edge of a layout table, have all the functions of a shear of unlimited strength and frame opening.

Interesting devices for cutting circles and complicated shapes, either one at a time or in multiple with several cutting heads, have also been developed. To a machinist, accustomed to the massive frames required to carry the loads imposed by a deep cutting tool traveling at high speed, the light frames used on the oxy-acetylene cutting machines seem distinctly fragile. However, a substantial foundation for carrying the work is the only heavy part required. The work of cutting is done chemically by a jet of oxygen, and all that is necessary is a substantial and accurate method of moving the jet at a uniform rate along the desired path.

One new and useful device, portable in that it weighs about 350 lb., yet capable of handling shapes falling within a 56-in. circle, mounts a full-sized templet (a steel plate "cut-out") on its upper works; around this a magnetic tracing wheel crawls and drives the cutting torch, mounted directly beneath. The templet may be

replaced by a board, carrying a full-sized drawing, and the outlines may be followed by a tracing wheel (motor driven for uniform speed) guided by hand. This tracing wheel above and blowpipe below are connected by a U-shaped arm reaching over from beyond the edge of the drawing board.

The same method of producing parallel motion between cutting flame below and magnetic templet tracer above has also been built into machines which traverse the area of the largest sizes of commercial plates. In such a device a carriage running on a permanent track lengthwise of the work table carries a little jib crane, along which a trolley may travel, carrying blowpipe and tracing device. Combined longitudinal motions of main carriage, swing of crane arm, and travel of trolley enables the flame to reach any point in the whole area. A substantial overhead frame suspends the templet. This frame is hinged at the rear so it can be tilted back to clear the table; thus heavy work can be handled by overhead crane.

Similar devices dispense with the overhead templet and mount it on a very large table at one side of the work. A simple pantagraph gear then connects tracing point and cutting flame, which may be 10 or 12 ft. away.

Special pipe cutting machines are also very interesting. A light one for field work consists of a central shaft, to be centered in the pipe-end by an expanding spider, and which carries the blowpipe on a radial arm geared for uniform travel around the pipe. Another is for shop work, and is designed to cut all the intersections needed, without the aid of templets. Suppose a 4-in. pipe is to branch off from a 10-in. pipe. The machine contains ways on which the 10-in. pipe is clamped. The blowpipe is carried on an axis which can be tilted at any angle and this axis is adjusted to intersect the 10-in. pipe in the correct point and direction. Then the cutting blowpipe or torch is driven in a 4-in. circle around this axis, thus automatically generating the proper intersection.

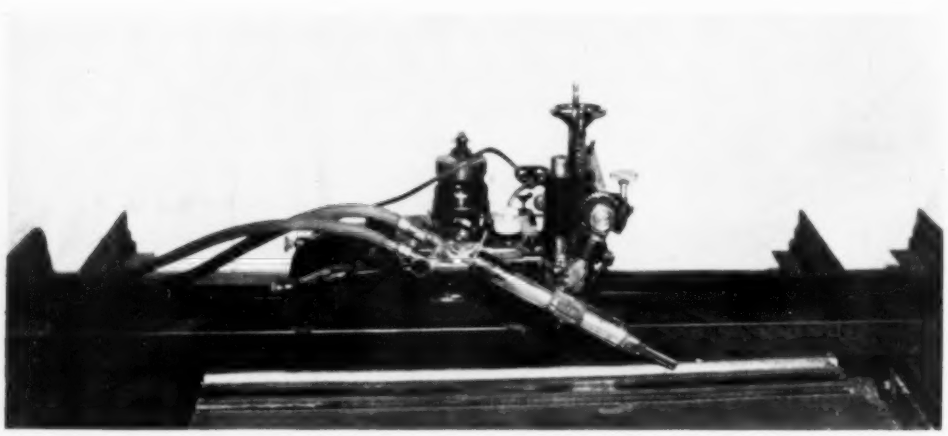
Improved Cutting Blowpipes

Much study has been given to the cutting blowpipe itself. It is not simply a matter of gas pressures and orifice diameters, but all passages must be of proper size and proportion, with outlet orifices perfectly shaped so that the gases can emerge with unhampered flow. Amount, size, and disposition of preheating flames immediately surrounding the cutting jet of pure oxygen also have influence on the quality of the work.

All this means that a slab 20 in. or 30 in. thick can be cut with oxygen in any desired contour or bevel to rather close tolerances. The photograph on page 37 gives visual evidence. In normal straight-line cutting, a good machine can work within a vertical tolerance of $\pm$ 0.01 in. on plate up to 2 in., $\pm$ 0.03 in. on 6 in., and $\pm$ 0.06 in. on 12-in. plate. Bevel cutting on straight lines can be done so that the lower intersection is accurate to 0.06 in. Shape cutting is accurate to $\pm$ 0.06 in. on all contours. Speeds and oxygen consumption in the table opposite are quoted from an article in *Oxy-Acetylene Tips* for November, 1932; the range in speeds represents the differences of unskilled and skilled workmen, conditions of material and facilities for the performance of the work.

It would appear to be only a short step from a bevel cut at a flat angle to a flame cut which does not go clear through the plate. This should gouge a channel in the surface. The photograph on this page shows a straight-line cutting torch so adjusted for flat work in abutting plates.

The cross-section of the channel cut in such a manner may be varied by the angle at which the blowpipe is



Flame Machining, Where an Automatic Cutting Blowpipe Gouges a Channel in Abutting Plates, Preparatory to Welding; Courtesy Air Reduction Sales Co.

set, the oxygen pressure and the speed. By using a modified cutting blowpipe wherein preheating flames are close-spaced at the sides of the jet a broad, flat channel is produced; concentrating the preheat along the center of the cut gives a cut of deep oval cross-section. Present economical limits for the oval cut are up to $\frac{1}{2}$ in. wide; for the flat cut up to 2 in. wide. Depths may vary from 0.05 in. to 0.30 in.

By appropriate and simple set-ups on lathe or planer, such cuts may produce forms like worm wheels and racks. Or if the successive cuts are made to overlap slightly at edges, the whole surface may be lowered. A given volume of soft carbon steel can be removed by this means from one to three times as fast as the best performance with high speed cutting tools. Oxygen consumption varies from 2 to $2\frac{3}{4}$ cu.ft. per lb. of metal removed. Both these figures are bettered by preheating the stock to about 600° F., and the margin of superiority over machine tools is even greater on harder and tougher materials.

Rate of Linear Travel in Straight Line Cutting of Low Carbon Steel Plate

Thickness of Metal	Speed Range in Linear Ft. per Hr.	
	Manual	Mechanical
1/4 in.	90 to 140	107 to 140
1/2 in.	85 to 130	89 to 130
1 in.	50 to 71	64 to 95
2 in.	36 to 46	44 to 60
4 in.	18 to 37	30 to 43
8 in.	11 to 19	21 to 27 1/2
12 in.	6 to 13	13 1/2 to 14 1/2

While the possibilities of flame machining are largely matters for the future to develop, two important industrial applications are already indicated. One is for scarfing heavy plates for welding — if two plates are butted it is merely necessary to run the flame down the intersection several times to deepen the groove nearly to the underside, and thus prepare the U-shaped opening desired for welding.

Billet Cleaning (Deseaming)

An even more important application of the principles of flame machining is for removing surface defects from billets, prior to rolling into pipe, plates, or bars. In this process the billets are first pickled in dilute sulphuric acid to remove mill scale, and an inspector marks the areas to be surfaced, and strikes the surface sharply with a 4-lb. hammer to push up a small nib of metal at the head of each area. The cutter, with a long-handled blowpipe, heats this little nib to incandescence in a second or two, then tilts the blowpipe's head so the flames are more nearly parallel to the surface and simultaneously turns on the cutting jet of oxygen. Immediately a white hot tongue of liquid iron oxide leaps out ahead of the flame, and the operator rapidly follows with the tip of the blowpipe.

It takes no more than 4 or 5 sec. to cut a shallow channel in a billet 6 ft. long. The gouge is about 1 in. wide with tapering edges (an essential condition to produce smooth rolled surfaces) and $\frac{1}{16}$ to $\frac{1}{8}$ in. deep depending on the inclination of the tip on the cutting blowpipe.

To establish the relative merits of the process, one of the larger pipe mills ran a comparative test of the costs of chipping with an air hammer, gouging with a heavy milling machine, and flame deseaming. A 75-ton heat of mild steel was divided in three piles for surface preparation; chipping costs together with amount of metal removed were estimated. The results were so favorable to the oxy-acetylene process that it is now used exclusively on all mild steel billets intended for seamless tubing.

Cutting Machine of Recent Design Beveling a 6-In. Slab. Carriage automatically moves down track at predetermined speed. Courtesy Linde Air Products Co.

Slag Control in steel making

The editor reports a symposium held by the Iron and Steel Division, A.I.M.M.E., at the recent Metal Congress. Slag control is necessary to control the iron oxide in solution in the liquid steel at the end of the refining period. If this is not at the proper amount the amount of deoxidizer cannot be predicted, the recovery of alloying additions (when made) will be erratic, the grain size of the steel will be out of control, and the steel will show variations in cleanliness, toughness, and machinability.

IT is a matter of historical record that the Swedes had no trouble in making steel with Bessemer's new process, but that several fortunes were lost by English steel makers who tried to do the same thing. Eventually (and none too soon) it was discovered that a liberal dose of high manganese pig iron would quiet the blown metal so it would stay in the molds and solidify into a sound ingot which could be rolled and forged. (Swedish pig iron had enough manganese at the start.)

Ever since that costly experience, steel makers have believed that iron oxide is poison to good steel, and iron oxide has very frequently been blamed for material off quality in any one of various respects, even though there was little or no actual evidence that oxygen or iron oxide or any other metallic oxide is soluble in solid steel. Even if they could not prove themselves right, their critics could not prove them wrong — a rather comfortable position!

Considerable knowledge about this question has recently been acquired, the most active agency in this country being the Pittsburgh Metallurgical Advisory Board's study of the physical chemistry of steel making. Its program and discoveries have been noted from time to time in METAL PROGRESS. They have included not only precise analytical studies of slags on and in the steel at various stages of the open-hearth process, but many full-sized experimental heats made in cooperating plants. From 1926 to 1934 this work was directed by C. H. Herty, Jr.; the plant work was supervised by C. F. Christopher.

The General Problem

The problem of steel making, stated rather briefly, is to put pig iron and scrap into a melting furnace, and burn out or slag off as much of the undesirable impurities as possible. The active reagent in this action is iron oxide, either formed by the furnace gases during melting, existing in the charge as rust, or added to the bath as iron ore or scale. According to the concepts of physical chemistry, this iron oxide has a definite solubility in the steel, depending on the temperature and the amount contained in the slag (and this has been proven experimentally). The problem then is to operate the furnace so that the iron oxide may be brought to the desired point at the end of the refining period — that is to say, the slag at the finish should be at a given state of oxidation for various grades of steel. The

oxide in the metal is later removed partially or fully by deoxidizers (such as ferromanganese, ferrosilicon, ferro-carbon-titanium, aluminum) added variously in the furnace, in the ladle, or in the mold. The nature and quality of the steel depends upon the skill with which these operations are performed and the degree to which harmful oxide or oxygen in solution is converted into harmless non-metallic inclusions.

The above ideas are no longer hypotheses; they rest on a large mass of precise experimental evidence. The sessions at the recent New York convention of the American Society for Metals on grain size (summarized in METAL PROGRESS last month) showed how the grain size of carbon steel is controlled by control of the oxygen content at the end of the heat and correct final deoxidation. Definite data as to steel making practice to attain these ends in medium carbon forging steel were quoted by Messrs. Epstein, Nead and Washburn. Rates of transformation (heat treatability) and numerous items of plant economy in fabrication depend on grain size.

Other definite data on toughness were determined during the Pittsburgh studies. They were summarized by Dr. Herty in his convention paper "The Effect of Deoxidation on Some Properties of Steel." Four steels with 0.15% carbon (made by four commercial practices) whose dissolved oxygen content varied from high to low were studied. High oxygen steel tested 44.0 ft-lb. Izod at room temperature and 2.0 ft-lb. at 40° below zero F. Low oxygen steel, on the other hand, tested 145.0 ft-lb. Izod at room temperature and 110.0 at 40 below!

Aging of steel sheet is an important characteristic. To measure "quench-aging" these same steels were oil quenched from just below the lower critical and aged at room temperature for two weeks; the high oxygen steel gained 10 points in Rockwell B hardness; the low oxygen steel gained only 2 points. To measure "strain-aging" other samples were cold rolled 15%, heated to 850° F. for 5 min. and tested 24 hr. later. High oxygen steel lost 88% of its original impact strength; low oxygen steel lost only 12%.

Steel for Sheets

Enough has probably now been said to establish the importance of iron oxide control in steel for present-day requirements. Hence the Iron & Steel Division of the American Institute of Mining & Metallurgical Engineers was warranted in devoting a whole day at the National Metal Congress to the matter of "Slag Control in the Making of Iron and Steel." Various commercial types of rimming and killed carbon steels and of forging grades made in basic and acid open-hearth and electric furnaces were considered by experts in the various practices. It was a series of papers notable for the specific data presented rather than a generalized discussion.

Typical was the paper by L. F. Reinartz of American Rolling Mill Co. (Chairman of the Iron & Steel Division) on "Slag Control in Rimming Steel"; wherein he treated the matter as but one phase of the entire operation from repairing bottom to tapping the heat and teeming the ingots. He emphasized particularly that success depended on uniformity of charge, heat to heat, and close attention to many minor details of melting and refining practice (which he listed). The bane of this process is excess silicon or silica in any form; the total charge should contain no more than 0.40 to 0.50% Si. Manganese in the pig iron should be about 1.5% — certainly over 1.0% — and work down to about 0.10% residual in the metal. More than enough limestone must be added than is required to flux the non-metallics in order to cover the bath properly; 9 to 10% limestone is a good figure. Part may be replaced by its equivalent of burnt lime, but some unburned stone is required to give action to the bath when making deep drawing steels or sheets for coating. Refining should be done under a relatively thin slag which should be thickened up with burnt lime to a creamy slag. Spar should be used very sparingly; an excess makes a watery slag and oxidized steel of poor quality.

Carbon should be reduced to within a few points of the desired figure with clean lump ore; final removal is done by poling with wood poles or rodding with steel bars. At tapping a heat with 0.05 to 0.07% carbon should have a slag with 30 to 35% FeO; 0.10 to 0.15 carbon should have 18 to 23% FeO in the slag at tap. If these figures are exceeded, the slag will be too thin and this is hard to correct — excess deoxidizers must also be used in the ladle. If the iron oxide is too low it can be brought up by scattering very fine ore or scale on it; all this should be digested before tapping. Mixture of slag and metal during tapping must be avoided, and the very small amount of slag left on the ladle as it is lifted out of the pit should have some lime sprinkled on it, to prevent slag boils while teeming.

A slag test will indicate the condition of the bath and from it the amount of deoxidizers is figured. For 0.10% carbon heats half of the

manganese is added to the furnace in 10-lb. lumps about 10 min. before tapping; the rest in finely crushed form goes into the ladle. For 0.05% carbon heats all the manganese should go into the ladle. Temperature is also important and should be 2925 to 2950° F. at tap and 2850 to 2875° F. at pour. If too cold it will be wild and gassy; if too hot will rise in the mold. Properly made steel will drop several inches in the mold, but then the metal gradually rises to fill this pipe.

Final deoxidation is done with aluminum with or without ferrotitanium (both practices are good, in Mr. Reinartz's opinion). Most operators underdose in the ladle and add a little aluminum in the molds, although the less there the better.

Quick Estimation of Oxide

As mentioned above, the amount of iron oxide in the steel at tap can be computed from a knowledge of the temperature, the FeO and Fe_2O_3 in the slag and the carbon in the metal. Effect of these variables on commercial heats has been worked out, and is stated in concise form in Cooperative Bulletin 68 of the Metallurgical Advisory Board, Carnegie Institute of Technology. The practical method of estimating quickly the FeO content of the slag (and inferentially of the steel) is most important, and was given briefly by C. F. Christopher in his talk at the meeting now being described.

In basic open-hearth steel the residual manganese in the steel is an excellent indicator of FeO in the slag. High manganese means low FeO slag, and vice versa, because its amount is controlled by the proportion of active oxides in the furnace slag.

Another quicker test — although just as indirect — for FeO in slag is its viscosity. In this test a spoonful of slag is taken from near the surface of the metal (remembering that in a fairly quiet slag the top layer is higher in Fe_2O_3, being oxidized by the furnace gases) and poured into a viscosimeter. This may be nothing more than a split mold with a pouring basin feeding a horizontal channel; fluidity is proportionate to the distance the slag runs into this channel before freezing, and fluidity tested during the course of the heat is an excellent indicator of the FeO in the slag. The viscosimeter may also be a steel plate about 6 in. wide and bent to give a flat pouring space and an inclined plane at 30° to the horizontal; the hot slag running down this plane freezes in a ribbon of certain definite thickness, and this thickness measured at an arbitrarily chosen point, say 6 in. from the top of the incline, is a direct indicator of the viscosity. (Normal creamy slags give a thickness of 3.0 to 3.8 mm.)

Of course, the results of the above quick tests apply only to a practice that has been well standardized as to raw materials, method of working, and end product, after they have been checked or correlated with the results of accurate analyses of metal and slag at the finish. It must also be determined what kind of steel will best suit the mill practice, taken as a whole, to meet the customer's requirements. In other words, the mill should be filled with steel containing a medium amount of iron oxide and its working studied before changing to another campaign on steel with higher or lower oxygen content. After the management determines what kind of steel is best, all things considered, that kind can be produced consistently by uniform charges, furnace practice, and slag control.

Dr. Herty emphasized the fact that these viscosity tests give an idea of FeO only indirectly, for SiO_2 in the normal slag is the oxide which has the most influence on viscosity. The amount of FeO in the slag is the result of two opposite influences — the absorption of oxygen from the furnace atmosphere, and the transfer of oxygen at the slag-metal interface to various metalloids in the steel. Thin slags transfer FeO to the metal rapidly, and thick slags slowly, the former resulting in low FeO slags and the latter in high FeO slags. Hence viscosity meeasures FeO.

High Carbon Steel for Forgings

W. J. Reagan of Edgewater Steel Co. showed how these same principles operated in the manufacture of killed steel, high in carbon (0.60 to 0.80%). In melting all cold metal it is desirable to keep the silicon in the charge as low as possible and add a minimum of lime. If this is done, the iron oxide content reaches a very low point (4 to 5%) before the charge is completely melted, and the metal melts to about 1.20% C. Further decarburization is done by ore additions and the FeO content goes up to 6 or 7% at the finish.

These low FeO contents are advantageous in several ways. In the first place, the FeO analysis in the steel is roughly 1/100 that in the slag, and less deoxidizer is needed. Rapidly melted heats came down to lower FeO in slag; hot furnaces tend in same direction and mean higher residual manganese — this in itself means 25¢ per ton saving in ferromanganese. Correct

(Continued on page 44)

AMERICA ON THE WIRE

AMERICANS get more out of the telephone than any other people in the world.

Partly it is because we still have the pioneer qualities. We are restless, inquisitive, ambitious, sociable, ingenious, enterprising. The telephone is adapted to us and we are adapted to the telephone. But another reason why the average American uses the telephone more is that there are more telephones to use—more than thirteen million in the Bell System alone. And the service is better.

There are few persons in this country so isolated that the telephone cannot find them. Because everybody knows this, the telephone is kept busy and everybody gets more out of it. Your telephone grows in value, the more you use it—the more you rely on it to help you through the day's activities.

BELL TELEPHONE SYSTEM

More than 57,000,000 conversations a day are held over Bell System wires. It takes a telephone system of great size to render quick, reliable serv'ce to a great nation.

furnace operations also decrease rejects so that actual yield is increased over 1%. It is also associated with a considerable saving in lime (perhaps 500 lb. in a 90-ton heat) and associated savings in handling and incidental losses. Saving in iron kept in the bath rather than slagged off as oxide represents one heat in about 60. Best of all, such slag control gives clean and uniform steels, as shown by comparisons of inclusion counts on two heats, one melted under high iron slag (15.45% FeO) and the other melted under low iron slag (10.41% FeO).

In discussion it was emphasized that the amount of FeO in the slag for the cleanest steels is not necessarily the lowest iron oxide you can carry in the slag. Residual manganese and the exact deoxidation practice both have an important influence, and the optimum slag analysis has to be found by trial. Likewise it is necessary to carry FeO up at times in order to drive the phosphorus down to a low specification, these two items being inversely proportional to each other.

Rail Steel

A. P. Miller and T. S. Washburn of Inland Steel Co. gave some data on "Slag Control for Recarburized Rail Steel." One good reason for limiting FeO in slags for such metal is to increase the yield (weight of ingots and butts to total metallic charge), but as noted above, iron oxide can't be lower than 9 or 10% else the slag loses its basicity and has no capacity left to absorb the phosphorus in the recarburizer. The upper limit should also be fixed because recovery of manganese from the ferro becomes variable as FeO in slag is higher, and it is then harder to hit the specified manganese range in the finished rails. Still another reason is that in such a high oxide heat it is harder to deoxidize the steel satisfactorily and the ingots show more segregation and the A-rails show a decreased ductility. It was emphasized that it is increasingly difficult to make rails as the size of the section increases, and whereas this difficulty resides in a number of factors, the iron oxide in the slag is one of the most important and attention is focused on it.

At Inland Steel Co. the aim is to have 12.5% or less FeO in slag when carbon is at 0.30% in order to finish at 15% FeO and 0.15% carbon just before recarburization. About 9½% of limestone, measured as to total metal, will be necessary in a charge with normal silicon to have a lime:silica ratio of 2.8 and 3.1 respectively at the two stages just mentioned.

Details as to the working of a typical rail steel heat were given by Messrs. Miller and Washburn. Selected scrap is melted as quickly as possible; ratio of scrap to hot metal is about 44 to 56. If slag is lumpy, spar is added, and this raises FeO 1 to 1½%. When carbon has been worked down to 0.30%, the slag should be creamy and quiet enough to warrant an FeO determination, and this gives an idea of how it will function 2 hr. later when recarburizer is added. During this last period, wherein spiegel is added in two batches, the carbon in the bath is brought down to 0.15% and the FeO in the slag rises to 15%. Just before adding recarburizer the bath is cooled, which lowers the iron oxide 1 to 1½%.

To quote the authors: "The problem of control may be summed up as one of selecting and balancing the initial charge, and of applying correctives in the working as quickly as they appear. When consistently followed, slag control has proved its worth, not only from the production standpoint, but also with respect to the furnishing of a product which is more satisfactory in service."

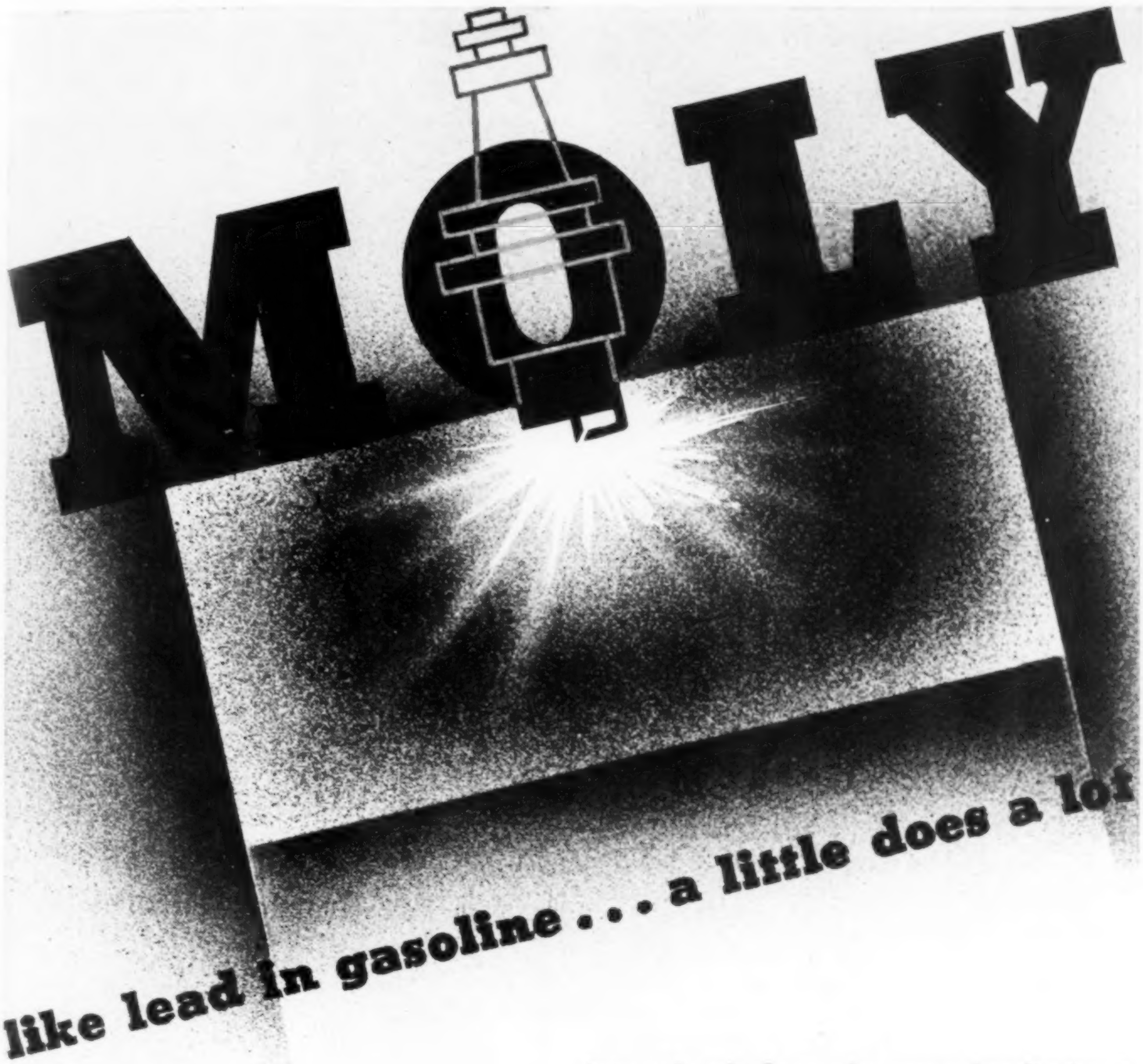
Electric Furnace Steel

Several speakers discussed various phases of the problem of slag control when manufacturing alloy steels in acid and basic open-hearth and electric furnaces. Among these H. F. Walther of Timken Steel and Tube Co. gave a comprehensive discussion of the principles of working a basic electric furnace, wherein he expressed the opinion that a 30-ton furnace (or even a 100-ton furnace) could be controlled as well as others holding 2 to 5 tons.

Manufacturing troubles have been so intensified by the short shift, and have caused so much argument as to which crew is responsible for a certain heat that a schedule of definite weights and approximate times is now made out in advance and the melter must have very good reasons before he departs from it. Actual time is a matter of permanent record for every heat.

Clean scrap and first class bottom materials are the fundamentals of good practice, in Mr. Walther's opinion. Dirty scrap means bottom corrosion, high magnesia slags and dirty steel. If the charge is melted quickly and evenly, the first or melt-down slag consists only of the lime charged plus the oxides formed on melting. It is seldom necessary to add ore, unless high carbon or bright scrap is in excess; otherwise rust

(Continued on page 48)



WHAT is probably the most remarkable of "Moly's" many qualities toward improving iron and steel becomes strikingly apparent in its use in copper-bearing ingot iron. *Less than one-tenth of one per cent* is known to allow the addition of twice as much effective copper in ferrous metals designed to resist atmospheric corrosion and that encountered in mildly acid or oil-refinery liquors.

In fact, service data show copper-Molybdenum ingot iron considerably more resistant to atmospheric corrosion than copper-bearing steels. And one oil refinery claims that in contact with corrosive oils at elevated temperatures this material has outlasted plain carbon steel by *more than three times.*

The outstanding development of modern metallurgy is unquestionably the growth in use of Molybdenum irons and steels. In countless uses and applications it has been definitely proved that Molybdenum increases resistance to corrosion, fatigue, shock, creep, abrasion and temper embrittlement in plain or otherwise alloyed irons and steels. Making heat-treated steels easier to machine and weld—without loss of strength—is another of its characteristics. And its ultimate possibilities have not yet been approached.

"The Moly Matrix" is our new house organ, planned to help executives and engineers keep informed of Molybdenum's progress. A simple request puts you on our mailing list. A further request brings you either or both of these new books: "*Molybdenum in* 1934" and "*Molybdenum in Cast Iron*—1934 *Supplement.*" And our metallurgists and experimental laboratory in Detroit offer ready assistance toward solving any alloy problems you may have. Climax Molybdenum Company, 500 Fifth Avenue, New York City.

In Canada—Railway & Power Engineering Corporation, Ltd., Montreal

CLIMAX Mo-lyb-den-um

"I'm POSITIVE these furnaces have saved us their cost in less than a year!"

In the words of users, Certain Curtain Furnaces pay for themselves in an amazingly short time, in actual dollars saved, entirely apart from the vastly improved quality of the work. The three major savings are:

1. LESS SPOILAGE

"Spoilage reduced to nothing."—"Total tool cost has decreased 25%."—"Have entirely eliminated tool losses due to faulty heat treatment."—"Hardened 2,000 hobs valued at $50 each without a single loss."—"Figures show definitely that our spoilage is less than half what it formerly was."

2. INCREASED PRODUCTION

"There has been a definite increase of 30% in our hardening production."—"We have increased production in our hardening room 20 to 50%."—"Savings through increased production and less spoilage amount to $570 per month."

3. LESS COST TO FINISH

"We have eliminated sandblasting and reduced grinding 66⅔%."—"The money saved by eliminating grinding paid for the furnaces in five months."—"We have completely eliminated grinding of tools used for our own production."

Equipment that would definitely improve quality without increasing cost, would indeed be a bargain. Yet Certain Curtain Furnaces not only greatly improve quality, but also yield 100% to 200% per year in actual savings! And remember these are not mere claims—they are USERS' STATEMENTS!

Send for new Bulletin:
"The 7 Points of Hardening"

C. I. HAYES, Inc.

129 BAKER STREET, PROVIDENCE, R. I.

E. F. BURKE 2281 Scranton Road Cleveland, Ohio	L. W. HAYDEN 26 So. Fifteenth St. Philadelphia, Pa.	F. J. CONDIT 148 Crestwood Ave. Buffalo, N. Y.
R. G. HESS 176 Fulton St. New York, N. Y.	L. C. LOSHBOUGH 2626 W. Washington Blvd. Chicago, Ill.	C. A. HOOKER 202 Forest Ave., Royal Oak Detroit, Mich.

ELECTRIC CERTAIN CURTAIN FURNACES
REGISTERED U. S. PAT. OFFICE

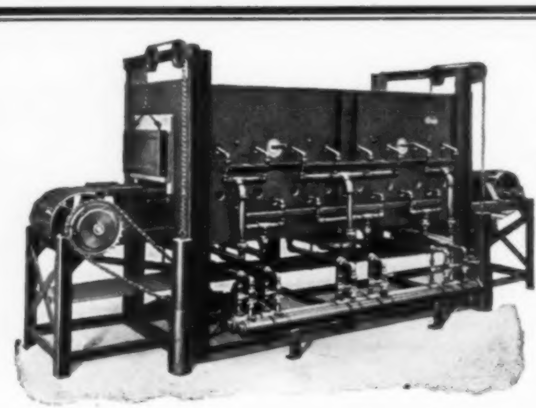
20% TO 40% ECONOMIES

IN THE CARBURIZING OF STEEL IS THE RECORD OF ____

CHAR CARBURIZERS

IN PLANTS BOTH LARGE AND SMALL

CHAR PRODUCTS COMPANY
MERCHANTS BANK BUILDING INDIANAPOLIS



No. 162 Belt Conveyor Heating Machine

Use American Furnaces

for . . . Greater Uniformity
. . . Greater Economy
. . . Greater Efficiency

WRITE FOR FREE BULLETIN

AMERICAN GAS FURNACE CO. PIONEERS IN 1878 LEADERS TODAY

AMERICAN GAS FURNACE CO.
ELIZABETH, N. J.

Slag Control

and oxidation during melting will take care of the carbon. It is important that this slag be cleaned quickly and *cleanly*.

Three types of second slags are used for alloy steels. The largest tonnage is finished under a "carbide" slag, which is good for most alloy steels containing 0.10% carbon or over. Another type suitable for low carbon and stainless steels is the lime-silica type. The third is the lime-alumina slag. Only the carbide slags were discussed in detail.

All materials used must be carefully dried, else hydrogen will enter the metal and cause porosity in the ingot tops — especially noticeable in the chromium steels.

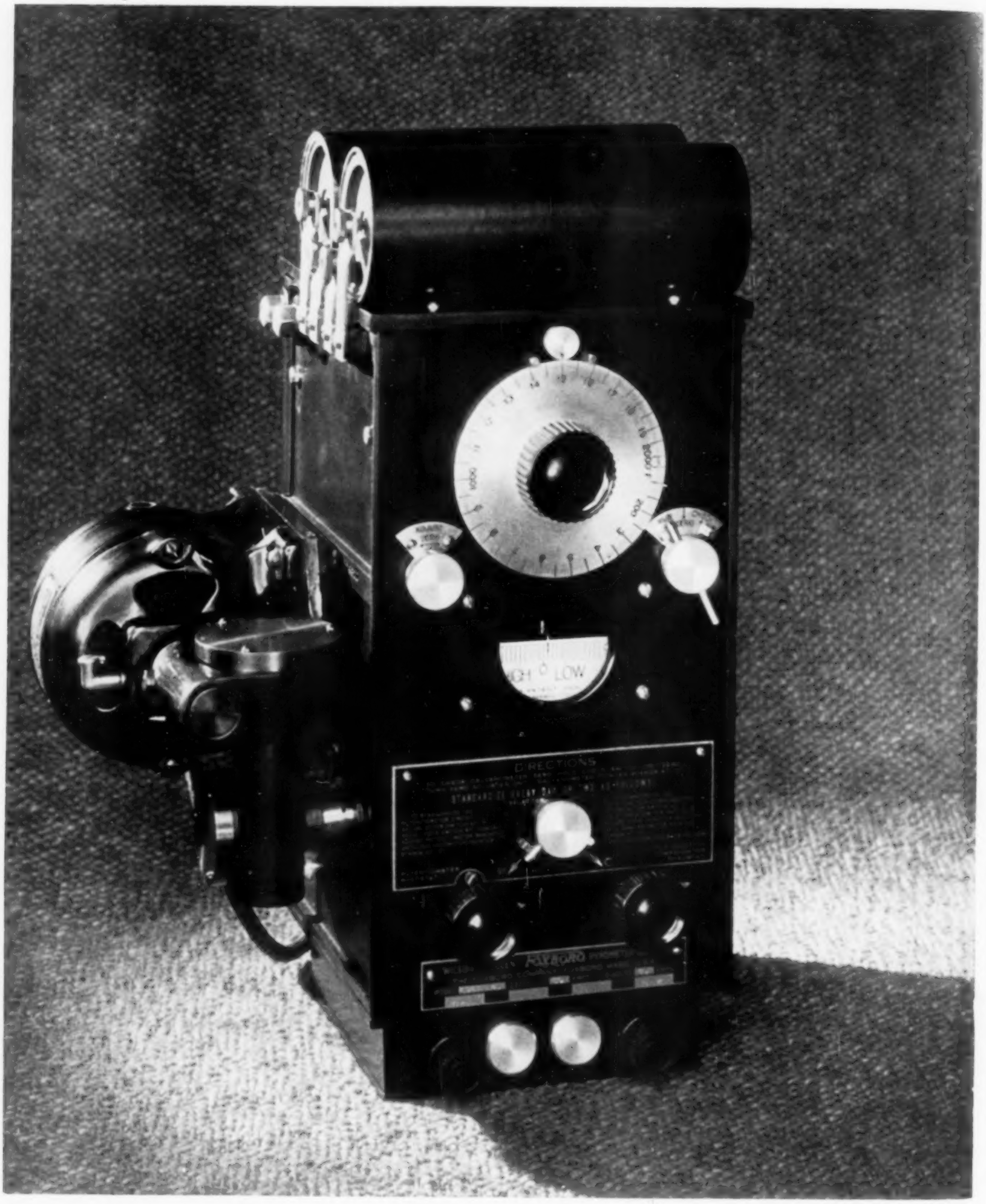
Analysis of the carbide slags will approximate 57 to 60% CaO, 22 to 25% SiO_2, 4 to 5% MgO, 1.5 to 2.5% calcium carbide, and less than 0.50% FeO.

Temperature of operation must be carefully watched. If too cold the alloy additions may be caught in the slag and trapped. Likewise, deoxidation products will not rise readily to the slag. On the other hand, if the temperature gets too high, lining and bottom are eroded and the roof drips, raising magnesia and silica in the slag, and causing difficulties from bottom contamination which will continue for several heats.

Operations must be done quickly. Pre-mixed slag materials should be added quickly as soon as the first slag is removed. As soon as the second slag is melted, carbon is spread over the slag in considerable excess — the generation of CO by its combustion creates a slight pressure inside the furnace and prevents oxygen infiltration.

The volume of the slag should be no greater than enough to cover the bath effectively and protect the metal from contact with the carbon floating on top, to protect the metal from direct action of the arc, and to insulate the metal from excessive radiation when in the ladle prior to teeming.

The time required for refining under the second slag should be minimized, not only to save power and furnace costs, but also because a long time at these high temperatures is harmful to alloy steels; 1½ to 2½ hr. will usually be sufficient, although even shorter refining periods have turned out excellent steel.



Free Literature

Sheet Iron Primer

The fifth edition of Republic's handsome 64-page booklet which tells the story of modern sheet iron in simple, non-technical language is now available. Gage tables and an interesting glossary of metallurgical terms are included. Bulletin Dc-8.

Cutting Steel

Recommended practices for gas cutting of structural steel are given in a concise and authoritative form by Linde Air Products Co. Qualification tests for good workmanship from the standpoint of accuracy and smoothness of cuts are also described. Bulletin Dc-63.

Multiple Point Records

A circular describing Leeds & Northrup's Micromax Multi-Color 6-point Recorder gives a reproduction of an actual chart in six colors showing how each numeral is printed in a contrasting color, thus avoiding errors and saving time. Bulletin Dc-46-A.

Aluminum Alloys

Working facts on aluminum — the properties and heat treatment of both cast and wrought alloys — are briefed for the manufacturer and designer in a booklet by Aluminum Co. of America. An appendix gives tables of physical properties, forms and sizes available. Bulletin Dc-54.

Everdur

Properties, applications, and forms available of this copper-silicon-manganese alloy are described by American Brass Co. High strength and corrosion resistance, ductility, weldability, workability, and moderate price are some of the advantages featured. Bulletin Dc-89.

Molybdenum in 1934

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Nv-38.

Multiple Tables

Ten convenient and simple tables in this booklet enable the steel user to tell at a glance either how long his stock must be to furnish a definite number of multiples, or how many multiples can be cut from a given length of stock. Bulletin Dc-71.

Hard Carbide

An extremely interesting little booklet describes "the hardest material ever produced by man for commercial use." This is boron carbide, and its manufacture, properties, and uses as an abrasive and as a wear resisting material are told by Norton Co. Bulletin Dc-88.

Air Draw Furnaces

Hevi-Duty Electric Co. offers a folder on their box type air draw furnaces for tempering, drawing, preheating, or annealing. Two types are available, one for temperatures up to 750° F., and one for 1250° F. Nv-44.

Cold Drawn Shapes

Many applications of cold drawn squares and flats are enumerated by Union Drawn Steel Co. in this folder. Sizes, grades of finish, and compositions available are listed. Nv-83.

Cyanides and Salts

R & H Chemicals Department of E. I. du Pont de Nemours Co. has a new 28-page manual on the procedure for case hardening, reheating, nitriding, and mottling of steels with cyanides, and on coloring, tempering, and drawing with salts. Nv-29.

Hardening Furnaces

The C. I. Hayes Certain Curtain electric furnace for the range 1200 to 1850° F. is described in this bulletin. Its applications to hardening of carbon, stainless, and alloy tool steels and to preheating high speed steel are discussed. Nv-15.

Grinding Carbides

A complete and detailed treatise on this important problem has been issued by the Carborundum Co. Special wheels and grits for the various commercial grades of carbides are given and many practical pointers are included. Nv-57.

The Lindberg Control

The Lindberg Control announced a few months ago for electric furnaces is now available for fuel fired furnaces. Controlling the input of fuel fired furnaces eliminates the lag caused by the protecting tube around the thermocouple and results in straight line temperature control. Nv-66.

Properties of Stainless

Carpenter Steel Co. offers (to manufacturers in U. S. A. only) a handy pocket size slide chart which gives at a glance a summary of technical data on all Carpenter stainless steels. Bulletin Se-12.

Metallograph

A new 36-page booklet of E. Leitz, Inc., contains all information on the Leitz large Micro-Metallograph, MM 1. Excellent photomicrographs are reproduced to show its capacity. Special attention is given to the darkfield illumination feature. Bulletin Se-47.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Non-Ferrous Annealing

General Electric Co. describes bell-type furnaces for annealing non-ferrous metals in a new folder which gives many data on operation and performance. Description is from technical rather than sales angles. Bulletin Ar-60.

Thermit Welding

Metal & Thermit Corp. offers a new booklet showing all the possibilities of Thermit welding, explaining the action, and telling in detail how representative Thermit welds can best be made. Well illustrated and clearly written. Bulletin Ar-64.

Manual of Pyrometry

Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

High Strength Steel

Cromansil steel, a development of Electro Metallurgical Co., has high strength and good ductility "as rolled" and is thus fine for structural applications where its great strength saves much dead weight. Bulletin Je-16.

11 Stainless Steels

Pertinent facts on 11 different types of Bethadur and Bethalon corrosion resisting steels are presented in a 40-page Bethlehem Steel Co. booklet. Advantages and limitations of each type are frankly presented. Bulletin Fb-76.

Hardness Testing

Men interested in hardness testing may find it worth while to read the recent catalog of Wilson Mechanical Instrument Co. which describes the latest design of Rockwell hardness testers and auxiliary work supports. Bulletin Sp-22.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. Bulletin S-27.

Blast Cleaning

A rugged blast cleaning cabinet for rapidly cleaning small work is described in a recent folder of Pangborn Corp. Full information on the operation of this machine is presented; many drawings and pictures are included. Bulletin Je-68.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Reports on Firebrick

Babcock and Wilcox Company offer a very complete set of Service Reports on Insulating Firebrick. These reports contain valuable data on adaptability of refractories and savings possible. Bulletin Ob-75.

Structural Bronze

Olympic Bronze, a high copper alloy containing silicon and zinc, is suggested by Chase Brass & Copper Co. for structural and engineering purposes. A new booklet gives many interesting details about its use. Bulletin M-59.

Heat Controller

As a companion instrument to their new indicating pyrometer, Foxboro Co. has introduced a new and inexpensive temperature controller which is dependable and easy to operate. Close control of temperatures is possible. Bulletin Mr-21.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

Localized Heat Treating

American Gas Furnace Co. offers information on production machines for localized hardening, tempering or annealing of tools, saws, springs, screws and machine parts of all kinds, using gas as fuel. Bulletin Ag-11.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is offered to those interested in pickling. A feature is a table of inhibitor strengths recommended for pickling various steels. Bulletin Ap-95.

Atmosphere Furnaces

An interesting folder of Surface Combustion Corp. gives performance data on their atmosphere furnaces in actual production bright annealing of ferrous and non-ferrous metals and carburizing, nitriding, forging and hardening without scale. Bulletin De-51.

Nickel Cast Iron's Uses

The role of nickel and nickel-chromium cast iron parts in such applications as fabricating sheet metal, pressing and forging is interestingly explained in a new pamphlet of International Nickel Co. Bulletin Ag-45.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

X-Rayed Alloy Castings

Electro Alloys Co. describes their X-Ray inspection of Thermalloy heat resisting castings for high temperature work. Considerable data on the use of X-Ray tubes and "radon" capsules to check foundry practice are presented. Bulletin Oc-32.

New Tempering Furnace

American Electric Furnace Co. has a new, low-priced electric air tempering furnace. It heats to 600° F. in 5 min. and to 1000° F. in 15 min., transferring heat to work 50 times faster than still air and 6 times faster than salt. Bulletin Mr-2.

Air for Furnaces

Users of gas or oil-fired furnaces know the necessity for a dependable source of large volumes of air at low pressures. A generously illustrated folder of Spencer Turbine Co. shows why their Turbo-Compressors give unfailing, economical air service. Bulletin Mr-70.

Small Spectrograph

A description of the small Littrow spectrograph and its uses is issued by Bausch & Lomb. Not a research instrument but a necessary tool, it brings spectrography within the reach of every plant and university laboratory. Bulletin Dc-35.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Metal Progress
7016 Euclid Ave., Cleveland

Please have sent to me without charge or obligation the following Literature described in the Dec. issue. (Please order by number only.)

....

....

....

Name ....

Position ....

Firm ....

Address ....

Type Metal

(Cont. from page 21) for alloys which oxidize easily would seriously complicate the problem. Type metals do dross somewhat but if they are properly handled the loss of metal can be kept at a low value. An associated problem is that of keeping the alloys at the desired composition, since the component metals do not oxidize in the same relative proportion.

This change in composition necessitates corrective measures which may be carried out in different ways. In one system the metal is allowed to deteriorate considerably, then brought back to normal composition by the addition of tin and lead-antimony alloys, the amounts to be used being calculated from an analysis of the alloy. In another system a special alloy is added during each remelting; in it the three metals are present in proportions which will offset the changes in the old metal, and the weight added is equal to the weight of dross removed. Periodic chemical analyses are made to catch any unexpected trend. A complicating factor is that all of the metal lost during remelting is not lost as oxide. Even with careful removal of the dross it may contain much unoxidized metal in the form of small shot.

The presence of non-metallic inclusions in an alloy would render it unfit for casting into type. A prime disadvantage would be the clogging of the tiny orifices, which are mere pin holes, into the casting chambers of the machine. When old type is sent to the remelting room it invariably carries a certain amount of foreign material, dried ink, paper fibers, and plain dirt. Fortunately the high density, fluidity, low surface tension, and other properties of the lead-rich lead-tin-antimony alloys are such that these foreign materials may be removed easily and quite completely by simple stirring and fluxing with some organic material such as a resin, oil, or wax on the surface of the molten metal. These substances also aid materially in releasing unoxidized metal from the dross.

Remelted and cleaned metal is cast into ingots of proper size and shape to be returned to the casting machines where it begins a new cycle. If demand for metal in stereotyping is heavy enough the metal may be tapped directly from the remelting pots back into the casting boxes.